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President's Page

Research Planning in Physics of the Atmosphere

The march of geophysics in these post-IGY days is so rapid and significant that important news comes from every side. In the last issue, the review of the Helsinki General Assembly summarized scientific progress in geophysical science, emphasizing our enlarged vistas of solar and terrestrial relations and of the solid Earth. The present issue turns to progress and plans to make possible new opportunity for geophysical research in meteorology.

The establishment of the National Center for Atmospheric Research, after three years of planning, represents a dramatic step forward to meet vital needs for the progress of meteorology as a global science. The new laboratory will rise on Table Mountain at Boulder, Colorado, in close proximity to the National Bureau of Standards and the University of Colorado. It is sponsored by the 14 universities that grant graduate degrees in meteorology in order to supplement their individual facilities for advanced and World-wide meteorological research. The AGU congratulates the leaders of these universities and their Corporation, the University Corporation on Atmospheric Research, the National Science Foundation, the High Altitude Observatory, the State of Colorado, and especially Dr. Walter Orr Roberts, who will direct this new meteorological center, for their solutions of difficult organizational problems, that have laid the foundations for this vital enterprise. The United States will now have access to facilities that are comparable to the scale of the problems of global meteorology, built in close juxtaposition to our related university facilities.

The new meteorological laboratory at Boulder emerged from the first report of the Committee on Atmospheric Sciences of the National Academy of Sciences, with which AGU has collaborated closely (see *Trans.*, June, 1959 pp., 95–111). Now the Academy Committee under Dr. Paul Klopsteg has issued a second report, summarized in this issue, on its studies of meteorological science, relating primarily to the governmental aspects of the science and the relation of governmental to non-governmental efforts to optimize meteorological research. We can anticipate that these recommendations will have further impact on the evolution of, and emphasis on, the scientific, as contrasted with the applied, aspects of meteorology. Out of this new outlook will emerge important new opportunities to advance the science.

Man is not content with his own atmosphere, and now turns to the atmospheres of the planets. The study of the planetary atmospheres by the Space Science Board of the National Academy of Sciences is also reported in this issue. Emergent from this study is the clear conclusion that our space scientific efforts relating to the planets could be advanced immediately from astronomical studies of the planets based on the Earth. Apparently, very few synoptic studies of planetary atmospheres have been made by astronomers. Until the advent of space vehicles, 'planetary astronomy' has not been accepted as entirely reputable. Then, too, surface telescopes suffered from scintillation and 'bad-seeing,' which has blurred the inferences to be derived. With the balloon telescopic methods of Professor Martin Schwarzschild and others, clear synoptic observations are now feasible. These can be made at far less cost than preliminary rocket flights to the planets, and can yield a long and consistent synoptic series. Because the range of hypothesis can be narrowed, such terrestrial observations could provide a sound scientific basis for eventual instrumentation of

the first, expensive, planetary space probes. We can hope that such precedent terrestrial efforts, too, will be realized before too long. This example, alone, illustrates the vital need for a very substantial fundamental, non-payload, oriented program of space research, so that our science on space probes can be put in the most advanced form, and can avoid preliminary and trivial experiments arising out of failure to develop fully the precedent knowledge that is within our reach on the Earth.

LLOYD V. BERKNER, PRESIDENT

Meteorology on the Move

PAUL E. KLOPSTEG

Chairman of the Committee on Atmospheric Sciences, NAS-NRC.

'Meteorology on the Move' is the title of the fourth in a series of reports by the Committee on Atmospheric Sciences, formerly Committee in Meteorology, of the National Academy of Sciences-National Research Council.[1] It carries forward an account of the activities of the Committee for the issuance of its first report in January 1958.

The following are members of the Committee: Horace R. Byers (Vice-Chairman), Henry G. Booker, Jule G. Charney, Hugh L. Dryden, Carl Eckart, Michael Ference, Jr., (Chairman after June 30, 1960), Paul E. Klopsteg (Chairman to June 30, 1960), Thomas F. Malone, Edward Teller, Fred L. Whipple, John R. Sievers (Executive Secretary).

The report begins with a summary of the findings and recommendations of the first report, and of the status of activities that were initiated following the presentation of that report to the Executive Department of the Government by the President of the Academy.

It then presents a discussion of the scientific progress in meteorology since that time, the most significant advance being a better understanding of the upper atmosphere. Other specific accomplishments are cited in dynamic meteorology, numerical weather prediction, general circulation and meteorological turbulence, atmospheric chemistry, and cloud and precipitation physics. The effect of ocean-atmosphere coupling on climate is emphasized.

Following this review the report undertakes to examine areas that may be dealt with insufficiently in the work to date, and puts forward findings and recommendations for action on matters regarded as urgently needing attention.

By joint action of the Committee on Atmospheric Sciences and the Committee on Oceanography, a study panel has been established to identify and formulate the problems arising in the air-water interface, leading to a report that will stimulate and guide studies relating to the interchanges of energy and matter between the liquid and gaseous components of the Earth's surface environment.

The report notes progress towards the establishment of a National Center for Atmospheric Research, following a recommendation made in its first report. On this subject it states:

'The Committee on Atmospheric Sciences reiterates its view with respect to the role of the National Center for basic research in the atmospheric sciences, namely, that under the competent direction and leadership which is assured for the Center it will become an effective unifying factor for all interests in the problems of the atmosphere. The Committee envisions a group of related, basic problems, the attack on which will become the focus of activity not only of the permanent staff, but also of the visiting scientists, regardless of institution or discipline, who have interests in them. These scientists, whether regularly associated with a Government agency or a university, will find unique facilities for their work at the Center. Moreover, we may confidently anticipate that procedures will develop which are designed to search out answers by cooperative effort, regardless of the disciplines which need to be applied, and without the inhibitions and barriers which appear almost insurmountable in an institution departmentalized along traditional lines, where "department" and "compartment" are almost synonymous.'

Another matter of much concern to the Committee is that of handling and exploiting adequately the great mass of information that will be coming soon from instrumented satellites as well as rockets and balloons. Those members of the Committee who are most fully informed on this problem estimate that within a very few years the daily deluge of data from these sources may exceed the total from all meteorological

[1] Publication number-794-pfNAS-NRC

observations heretofore made. The information must be quickly made available in usable form to scientists capable and desirous of using it, whether for research or for new forecasting techniques. The Committee states that 'It would seem difficult to assemble all the desired competence in a Government laboratory, either in the U. S. Weather Bureau or in the Department of Defense,' although there will have to be contributions by both groups towards reduction of data and application of results in practice. Therefore, it suggests the need of a centralized organization to enlist the cooperation of a large number of scientists from universities and elsewhere, and sees in the National Center an instrumentality well suited for the tasks ahead. The Committee accordingly '*strongly recommends the fullest participation of all institutions, public and private, Government and non-Government, in advancing the research potential of the National Center for Atmospheric Research, with a view to the earliest possible realization of the benefits which are sure to come out of the joint effort for which it will provide the means.*' A thumbnail sketch is included of the events leading towards the realization of the Center, with reaffirmation of the recommendation in the first report. In March 1959 the Committee, in regular meeting, unanimously endorsed the basic plans that had been evolved by the University Corporation for Atmospheric Research through painstaking studies by a competent staff under the direction of Thomas F. Malone. In its resolution it recited the needs which would prospectively be satisfied by the establishment of the Center. Moreover, the Center is regarded as an exceedingly promising prototype agency, with great potenital for rapid advancement of knowledge and for consequent application of that knowledge to human needs. It may become a pattern to follow in other broad fields of science.

Another subject of great importance is the field of experimental techniques by which rapid gains in atmospheric research may be made. The report poses the questions: 'What significant measurements are needed? What new experimental techniques are available for these measurements? What problems can be formulated to encourage further research in experimental methods? What new experimental problems arise as the result of the availability of satellites?' Other questions along similar lines may be asked. The report then tries to provide at least partial answers to these questions. With a view to getting on with the undertakings thus suggested, the Committee recommends that '(*1*) *the program considered here be divided into a number of symposia to be held over a period of a year or so;* (*2*) *the symposia, following a pattern set by the Gordon Research Conferences, be sponsored by interested universities, the National Center for Atmospheric Research, the American Meteorological Society, or the American Geophysical Union, or under joint sponsorship, aided with suitable grants from one or several foundations; and* (*3*) *prepared papers and summaries of the discussions be collected in the form of a book or monograph.*'

Finally, the Committee takes note of the report of the Special Advisory Committee to the Department of Commerce ('Kelly Committee') entitled, 'The Role of the Department of Commerce in Science and Technology,' and regards with approval those recommendations that provide for its suggestions of assistance to the Weather Bureau, in the areas of the Bureau's responsibility, including expansion of its needed research and development within the Bureau.

The last section of the report is a one-page summary of the Committee's recommendations.

Needed—Three Wise Men[1]

WILLIAM C. ACKERMANN

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For years Hydrology enjoyed the position of being the largest Section in the American Geophysical Union, and we contributed something like 40 % of the scientific papers in the *Transactions*. It was a rather comfortable arrangement, because we were numerically dominant in a prestige organization.

Starting in January of 1959 something strange started to happen. Our familiar gray publication got a new name and a yellow cover, and there were some articles about outer space. This was not objectionable, because outer space had become a very popular subject in the World, and we took a certain amount of pride in being associated with it. As the months went by it became a bit troublesome, because the publication became larger with almost each monthly issue, and it was becoming difficult to find items about hydrology. Some complaints came along later in the year, and these gave rise to a letter from the President of the Section. We were still getting as many papers dealing with hydrology as ever, he said, it was just that there was more of this new material.

By the time of our Annual Meeting in the spring of 1960 there was plenty of rumbling. Not only was there now a page charge, but the page charge was to be increased. Some members of the Section said they didn't want their printed efforts lost in outer space, and so they published elsewhere. Other members spoke of resigning from the Union.

The President of our Section was well aware of all this, and strove to find a solution. The problems were discussed fully with the officers of the Union, and he was told in effect that we were parochial in our outlook. We should be interested in outer space, and had better get busy working out the hydrologic cycle for the Moon, Venus, and Mars.

The matter of a separate Journal for hydrology was explored, and some conditions were set. The really scientific papers would continue in the Journal of Geophysical Research, and descriptive or applied pieces could go in a separate journal. Of course we would have to pay extra for this privilege. More recently the matter was explored with the Presidents of other Sections, as to whether the total subject matter could be divided between fluid geophysics and all others, or terrestrial geophysics and space geophysics. My latest information is that only the Section of Oceanography supported us in this.

While problems within the Union have been mounting, brickbats have been coming from a quite different direction. Probably some of you have read or seen the recent book, 'New Water for a Thirsty World.'[2] It is authored by Michael H. Salzman, whose only qualifications as a hydrologist I could find in the book were stated as 'Jack of all trades and master of four or five.' Some of the things he has to say about us are interesting, and I will quote a few of his many references to hydrologists and hydrology. The first quotation is from the Foreword, by Aldous Huxley, to Mr. Salzman's book.

> 'It remains to be seen whether those who are now regarded as experts in the field of hydrology and the politicians whom they advise will also agree that a good case has been made and that large-scale experimentation is in order. Vested interests are of many kinds. There is the intellectual vested interest of those who have taken their doctorates in a science at a certain stage of its development, who have taught and applied that science at that particular stage, and who regard any

[1] A talk prepared for the Pacific Northwest Regional Meeting of the American Geophysical Union, at Moscow, Idaho on October 19, 1960 by Vice President Ackermann, Section of Hydrology.

[2] Published by Science Foundation Press, Los Angeles, Calif.

questioning of the postulates underlying that science at that stage as a personal affront and a menace to their position in the Establishment.'[1] In his book, Mr. Salzman writes as follows:

'Most present day hydrologists, whether they work for a governmental agency or as consultants in private practice, whether their initial training has been in civil or hydraulic engineering or in ground water hydrology, have been so thoroughly indoctrinated and inculcated with the methodology and technology based on the applications of the hydrologic cycle theory that, when faced with a water shortage problem for a particular area, they seek a solution only in terms of their training and experience.

'It stands to reason, however, that there must be some recognition, by at least some hydrologists, that geochemistry accounts for the addition of some water on the earth and that, therefore, it is a conscious delimiting among some, as well as a mental block among others, that excludes these waters from the science of hydrology.

'If people in the field of hydrology wish to delimit their science, exclusively to applications of the hydrologic cycle and hence to the exclusion of the water of internal origin, they may certainly do so. Unfortunately, however, governmental officials, legislators, and the general public are generally unaware of these internal waters and are therefore under the delusion that hydrologists are the water supply experts without realizing that these experts deal with only certain kinds of water, namely the runoff of precipitation or its infiltration in porous rock materials. It is indeed remarkable, as well as incongruous, that those to whom the world looks to for the solution of water shortages can be so disinterested as to relegate the study of the waters of internal origin to other branches of geology.

'Despite the fact that hydrologists profess, among themselves at least, of their non-interest in and their scant knowledge of the waters of internal origin they nonetheless persist in continuing to delude themselves and the public at large. This is accomplished by either a failure to mention the existence of these waters, or by minimizing the amount of such waters, or by deprecating the usefulness or the quality of these waters.

'The arguments put forth obviate the necessity of a scientific rebuttal. Nonetheless, their position is being presented here in order to expose the type of thinking, not only of that of the authors, but common to many people currently engaged in trying to solve the water problems of our country. They are loyal, hard working, well meaning and able, but unfortunately their training and work does not leave them with an open mind.'

While we hydrologists are catching these brickbats on the one hand, there comes what looks like a gentle nudge from our good friends in the American Society of Civil Engineers. The Research Committee of the Hydraulics Division of ASCE prepared a report on 'Examples of Research Projects Needing Support in Hydraulics.' In this report I find the following:

'For many years hydraulic engineering has been concerned with the management of the larger streams—for irrigation, water supply, navigation, waterpower, or flood control. Large streams tend toward uniformity and so generalized measurements of rainfall and runoff were usually sufficient to provide necessary information for the engineer. However, there is increasing public concern with the smaller streams, which reflecting in closer detail the difference in terrain, vary greatly among themselves and vary greatly in response to changes in management or land use. The diversity among the smaller streams is so great that generalized rules, implied in such familiar tools as the unit hydrograph or channel-storage routing, are no longer satisfactory.

'The solution of the hydrology of upland streams—the evaluation of the effects of vegetation, soils, and land use on runoff and ground-water recharge, or the determination of flood peaks—can only be explained by understanding how rainwater reaches the stream or the ground water. A host of measurements on rainfall input and runoff output from small watersheds are available, but there is as yet no general theory to explain the course of mechanics of the flow from input to output.

[1] From Foreword, by Aldous Huxley, to *New Water for a Thirsty World* by Michael H. Salzman.

In the absence of a proven theory, a given set of data on rainfall and runoff apply only to a given set of field conditions (hence there is no way of applying the results to other areas). A general theory must be based on the mechanics of the flow of water in thin films over the surface of the land, through the nonsaturated soil media, the development of ephemeral zones of saturation in the soil, how a changing moisture content affects the hydraulic properties of soil, and of the flow of water into the streams from the permanent and ephemeral ground water.

'The emphasis in hydrologic upland research should shift from the collection of data to an examination of the details of the mechanics of the flow of water from the time it strikes the land surface until it reaches the ground water and ultimately the streams. The leading research on this subject is now 25 years old. Aside from Izzard's work on the mechanics of overland flow, very little progress has been attained since then.'

Other people are also moving into the partial vacuum in which we seem to exist. Geographers and economists are water experts, and upon occasion some lawyers also fancy themselves to be hydrologists.

Just this week I received an announcement of a new publication entitled 'Water Supply' by Hershleifer, DeHaven, and Milliman. Inasmuch as water supply is my business it was a surprise to see a new book authored by unfamiliar names. Upon closer check it developed that two of these men are economists and the third is a physical chemist. The book, of course, deals extensively with our water resources including the hydrologic cycle.

What is the state of our science that geographers, economists, and lawyers can speak for us these days? Is the science like the multiplication table that doesn't take a mathematician to understand? Or is our science like an early arithmetic that hasn't yet progressed to algebra, geometry, calculus, and beyond?

Perhaps there are many ways of judging the state of development of our science, but I will cite just two sources to indicate that ours is still a primitive science. For the first I would cite the 1960 publication '*Design of Small Dams*' by the U. S. Bureau of Reclamation. I have every reason to believe that this comprehensive book is up-to-date and employs the latest available scientific and engineering methods. In a section on *Estimating Runoff from Rainfall* starting on page 32, here are a few quotations:

'However, the infiltration rate approach is applied on an empirical basis to obtain a practical solution to the problem of determining amounts of runoff, recognizing that the values used are of the nature of "index" values rather than "true" values. Natural events are studied and the difference between rainfall and runoff determined. Since this difference includes all the losses described above, it is usually called a retention loss or retention rate. Such retention rates derived from available records may be adjusted to ungaged watersheds by analogy of soil type and cover.

'Two methods may be used to determine rainfall excess: By assuming a constant average retention rate throughout the storm period, and by assuming a retention rate varying with time.

'Because the use of a varying retention rate requires a complicated method of computation, and because present knowledge of the exact shape of the infiltration curve is rather limited, it is often preferable to assume an average retention rate (sometimes referred to as infiltration index) with an estimate of initial loss being made if antecedent conditions are relatively dry.'

Mind you, I am not quoting this to be critical of the Bureau of Reclamation—I believe this is the best we can do.

Let me cite another example. Back in my own State, Illinois, our agency recently completed an exhaustive study of rainfall intensity, frequency, and duration. This has been welcomed by a number of agencies who will use it in the formula $Q = CIA$, for estimating peak discharges. This is an ancient method, and we are still guessing at the values of C.

We have had some great men in hydrology, and we have been riding on their coat tails for twenty years. I'm thinking of Robert E. Horton, W. W. Horner, and L. K. Sherman, who were once called the Three Wise Men. I am thinking also of Daniel W. Mead, Adolph Meyer, and Merrill Bernard. These men were giants, and it is interesting to note that even today much of their writings is still current. For example, the

procedure for determining runoff from rainfall, to which reference has been made in the recent Bureau of Reclamation publication, was described exactly by Horton, in 1937. This is a paper entitled, *Determination of Infiltration Capacity for Large Drainage Basins*, published in volume 18 of the *Transactions*, American Geophysical Union. Horton, of course, did much more in developing the theory that we use today. A list of publications authored by him, and by Horner and Sherman, is most revealing.

Everthing that I have said to this point has been background. What can one conclude from this, or at least, what do I conclude from this? In the first place, I conclude that we cannot blame all of our problems on somebody else. We can't be like Johnny's mother who said that all the other soldiers were out of step. Frankly, *we* need to get in step and to come forward with some new ideas, and soon.

The 1930's and early 1940's had a great deal to do with the men who pioneered the science of Hydrology. These were the times when the soil conservation programs, the watershed programs, and the flood control programs made their starts, and the reclamation program expanded greatly. There was urgent need for new scientific knowledge to give correct technical guidance to those programs. And—as is so often the case in history—events did much to produce the men and their works.

The center of emphasis has shifted today, but never in the history of our country has there been more concern with water. I think that the increasing complexity of our water problems will require an expansion of research, and will result in new break-throughs in our understanding. It must come, and we must see to it that hydrologic findings are made by those best qualified to make them—the hydrologists. I think that the time has come when we again need three wise men.

What about the AGU and the *Journal of Geophysical Research*? My plea to you is to fill the *Journal* with hydrology. We can reverse the trend of the past two years and literally make it burst with papers on hydrology. So far as I know there is no limit on the number of papers we can submit, and so far as I know, no adequate paper has been rejected during these past two years. There are excellent papers on this very program today and tomorrow. When you authors get home, submit these papers to the editors of the *Journal*. Let's crowd our way back into the prominence we once enjoyed so easily.

If you don't write, or if you write and send your papers elsewhere, the Section of Hydrology will fade away. This would be a serious loss to Geophysics.

We don't have any other home except in the AGU, and no other organization is as logical and desirable a place for this science. No one outside of the Section is too concerned about us. I urge you, individually and together, to meet this challenge.

Report of
Conference on Planetary Atmospheres
held by
The Space Science Board, National Academy of Sciences,
at Arcadia, California, June 24, 1960

INTRODUCTION

A capability for launching heavy payloads of scientific equipment to investigate other planets of our solar system can be anticipated within the next few years. It is to be expected that the first investigations of other planets will involve direct measurements of the atmospheres of these planets, even before scientific apparatus is landed on their surfaces. Such scientific studies, probably first of Mars and Venus, are important, not only to the investigation of the planets themselves, but may also be expected to contribute substantially to information concerning the origins of the solar system and of the Earth.

For these reasons the Space Science Board of the National Academy of Sciences held a one-day conference in June 1960 to (i) discuss the present state of knowledge of planetary atmospheres as known from ground-based observations, (ii) consider the most important characteristics of planetary atmospheres about which additional information is needed and (iii) discuss, in a preliminary way, the experiments which should be undertaken to obtain the answers to questions raised in (ii).

The conference was moderated by Dr. L. V. Berkner, Chairman of the Space Science Board. Participation in the conference was drawn from several of the SSB committees, augmented by a number of invited participants. Those who attended were: L. V. Berkner, Horace W. Babcock, Warren W. Berning, Henry G. Booker, Harrison S. Brown, Joseph W. Chamberlain, Gerald M. Clemence, A. D. Code, N. W. Cunningham, Richard Davies, G. de Vaucouleurs, Earl C. Droessler, Maurice Dubin, J. B. Edson, Von R. Eshleman, John W. Evans, John Findlay, Robert D. Fletcher, Herbert Friedman, Roger Gallet, Stanley M. Greenfield, Frederick T. Haddock, George H. Herbig, Harry H. Hess, Seymour Hess, A. R. Hibbs, Hans Hinteregger, Norman Horowitz, Mark Inghram, Robert Jastrow, David Johnson, Geoffrey Keller, William W. Kellogg, C. Gordon Little, Gordon J. F. MacDonald, Laurence A. Manning, John E. Masterson, Yale Mintz, A. O. C. Nier, Nancy G. Roman, Alan H. Shapley, Samuel Silver, Shirleigh Silverman, William H. Sinton, Lyman Spitzer, M. J. Stoller, Verner Suomi, George Sutton, Harold C. Urey, Willis Webb, Harry Wexler, William Widger, Jr., and the Space Science Board Secretariat: Edward R. Dyer, Joel Orlen, J. P. T. Pearman, and R. C. Peavey.

The conference plan provided for the introduction of the following specific topics by specialists on each subject:

Broad review of current knowledge—Harold C. Urey
Photochemistry—J. W. Chamberlain
Atmospheric constituents, models and scale heights—G. de Vaucouleurs and W. H. Sinton
Meteorology of planetary atmospheres, including dynamics—Yale Mintz
Ionization and effects of magnetic fields—J. W. Chamberlain
Conclusions—Harold C. Urey

The transcript of the conference has been edited by the principal discussants. Mr. R. C. Peavey, Secretary of the Space Science Board, assumed over-all editorial responsibility.

MORNING SESSION

CHAIRMAN BERKNER: This meeting has been called to discuss the present state of our knowledge of planetary atmospheres, to consider what are the most important characteristics about these atmospheres on which we should like new information, and to discuss space experiments that can obtain the answers to these questions.

Within the next two to four years we shall

have heavy payloads available—not of the order of 100 to 200 pounds, but of the order of several tons. It is my opinion that Science is not yet ready for these heavy payloads. When the engineers call upon Science to supply them with experiments to fill the payloads, there is a serious possibility that some very superficial experiments will be thrown together hurriedly. It will be impossible to undertake the really intelligent things that should be undertaken because the necessary basic work will not have been carried out.

With the coming of the Thor Agena and the Atlas Agena, we shall be able to launch large payloads. Certainly, with the coming of the more advanced Saturn and Nova vehicles, and looking beyond that to the 1970's, perhaps to a clustered Nova type of vehicle, one sees payloads of the order of hundreds of tons. I think there is a fair probability that, unless we move very promptly in directions that I think the Board must decide, the scientific activity will not justify the expenditure of launching these very heavy payloads. It would be a great pity if Science, indeed, could not exploit the full opportunities that these heavy payloads provide.

It will take elaborate apparatus to do the job. Whether or not to use men will be a serious question. If it takes several hundred tons to put a man on the Moon or on the planets, we must face the fact that you can do much with 200 tons or more of scientific apparatus, provided you have asked the right questions, and you have developed the apparatus necessary to provide answers and to get them transmitted back to Earth. Man is in competition with many tons of first-class scientific apparatus. If the apparatus is not well conceived, and consequently Man is dispatched to do an inadequate job, the planning of our space science program will be at fault. This is not to say that Man cannot do a very useful job on a planet, but this in itself needs very careful scrutiny.

Basically, we want to know the chemical compositions and the electrical properties of the atmospheres. We surely want to know about the meteorology. We need to know something about the circulation of the atmospheres and why the circulation properties exist. What is the nature of the clouds? Under what circumstances does convection occur? One can, in fact, ask a series of questions about the atmosphere.

To provide a general background for our discussions here we have asked Dr. Urey to give us, first, a broad review of the current knowledge of planetary atmospheres.

DR. UREY: Trying to give a comprehensive review of the atmospheres of the planets in a short period of time is simply impossible, and we have in this room a great many experts who, in may ways, surely know as much, or more, about the atmospheres of the planets as I do. Hence, in trying to review what we know about the planets, I will be very brief.

As we study a subject of this kind it becomes fascinating simply because of the array of facts and relationships that we are able to deduce. We are interested in how the atmospheres evolved. We are interested in them as one detail of the past history of the solar system. We are interested in how the present structures of the planetary atmospheres bear on the structure and history of our own atmosphere.

Our solar system is quite important, from the standpoint of the evolution of stars generally, because detailed knowledge of the planets of our system will surely give us information regarding the evolution of a star such as the Sun, and this, in turn, will bear on much broader questions. Of course, throughout all our discussions we are interested in the question of life on the other planets, and the bearing that this has on the origins of life in general.

Certain things in regard to the planets and terrestrial planetary atmospheres are, I believe, generally accepted at the present time. I am quite sure that all of us in this room would be strongly prejudiced in favor of the view that the planetary atmospheres started out in a less oxidized condition than now exists.

It would be difficult for us to specify what the state of oxidation was at the beginning, and in fact it might be difficult to define what we mean by 'the beginning,' for one can hardly say, on the basis of any reasonable hypothesis in regard to the origin of the planets, what 'the beginning' was, the origin being a continuous set of events. Suppose, however, that we consider the time when the surface of a planet was well established, its size was fairly well determined, and it had settled down to a rather slow evolutionary process in the lsoar system. We would expect the atmosphere at that time to be more reducing than now.

In a way this goes contrary to geological doctrine, namely that the Earth has had very much the same sort of conditions on its surface throughout its history as it has now. Of course, this doctrine evolved at a time when we knew much less of the history of this Earth than we know now, and also at a time when, perhaps, we were less interested in going as far back in the history of our planet. Certainly, for the last five hundred million years, or even longer, we can expect that the atmosphere of the Earth was very similar to the present, and all the evidence would, I think, fit this. We begin to argue questions of this kind only when we get back to much earlier times than the beginning of the Cambrian period. Then the questions arise as to whether the atmosphere was hydrogen, and therefore strongly reducing, or perhaps one that,—having lost its hydrogen,—contained methane and ammonia, and whether an oxidation state of something like zero for carbon—that is CH_2O or elementary carbon—may not have represented, approximately, the reduced condition. Perhaps some people will question that carbon dioxide was present from the beginning, but we generally suppose a reduced atmosphere.

Since about the turn of the century, when Jeans gave us his escape theory of planetary atmospheres, we have been able to understand why the reducing atmosphere could change consistently into an oxidized one. The existence of free oxygen now on the Earth may be due to plants. It may be that, if the plants should disappear, free oxygen would also disappear suddenly within a relatively short time. In other words, the existence of free oxygen may be a peculiarity of plant life on this Earth.

On the other hand, Mars' atmosphere contains carbon dioxide, and so far as we can detect and identify them at the present time, any important quantities of carbon-hydrogen compounds do not exist in its atmosphere. I think Dr. Sinton may mention later his observations in connection with the CH vibration frequency, which seems to be present on the surface of that planet.

Venus has an enormously thick atmosphere of carbon dioxide—a kilometer atmosphere above the cloud layer, according to the observations of various people, probably the most reliable being those of Dr. Herzberg. What exists below is debatable, particularly because of the great difficulty in understanding the temperature distribution on the basis of recent evidence. Possibly, as Hoyle suggested some years ago, hydrocarbons exist below the surface in this planet. We expect that a planet would be formed with a certain amount of water and reduced carbon. If the water exceeds the amount of carbon in oxidation equivalent, we can expect that all the hydrocarbons will disappear and that carbon dioxide or carbonates and water will be left. On the other hand, if the proportion of water is less than the amount of carbon, we may find large amounts of carbon dioxide and hydrocarbons left on the surface, which fits very nicely with Hoyle's ideas. The thermodynamically stable forms for compounds of this kind are carbon dioxide, water, and then the completely reduced form—at least so far as methane is concerned—and the simpler hydrocarbons.

The questions of Mercury and the Moon are hardly worth discussing, because of the very small amount of atmosphere expected to be found or, in fact, detected, in either case. There is a very slight indication of an atmosphere on Mercury. Because it rotates once in its year and has the same face turned toward the Sun, the back side of the planet is one of the coldest spots in the solar system; hence condensation of some atmospheric gases may have occurred on that side of that planet.

The major planets, I think, will not concern us for some time, so far as our attempts to observe them more closely are concerned. We can deduce their compositions from their densities. Jupiter has a density of 1.33 g cm^{-3} and has a mass equal to 318 Earth masses, meaning, of course, that the interior of the planet must be at a high pressure. Hence, some low density material must be present in that planet; it has been supposed that this is hydrogen and helium. Saturn has a density of 0.7 g cm^{-3}, and it has a much smaller mass, about a third the mass of Jupiter; hence, the pressures there are not so large, and again it is a reasonable assumption that Saturn contains a considerable proportion of low density elements, i.e., hydrogen and helium, in its composition.

The densities of Uranus and Neptune are known to be 1.56 and 2.22 g cm^{-3}, considerably greater than those of Jupiter and Saturn. One

has 14.58 and the other 17.26 times the mass of the Earth. They are considerably smaller than Jupiter and Saturn, and yet they have very much higher densities. It appears, therefore, that the light elements, hydrogen and helium, have been lost from these planets.

I have stated what I thought was good doctrine until a short time ago. Then, in April, Zabrisky of Princeton presented a paper at the National Academy of Sciences in which he stated that the ratio of hydrogen to carbon in the atmosphere of Jupiter is very much less than the cosmic ratio. I had estimated, on a very simple assumption, that this planet has cosmic composition, and that there was 270 kilometer atmospheres of hydrogen above the surface of the planet; Zabrisky found five. It is a little difficult to understand why hydrogen would stay below the surface of Jupiter, and methane would rise above it. Possibly a mechanism involving metallic hydrogen, or something similar, would do this, but it is not at all obvious that this would be the case. If this rather rough estimate is correct, apparently Jupiter has lost hydrogen in its formation. However, something must have remained behind to contribute to its low density as compared with the other planets, and we would assume this to be helium. It is a most interesting fact—if it is a fact—that Jupiter has been able to lose its hydrogen and keep its helium. We will wish to examine this possibility repeatedly in the coming years.

In a recent private conversation, Gold expressed the view that Jupiter must be very hot on the inside. This would indicate that its low density is due to helium at a high temperature, Jupiter not having been able to cool off in all of geologic time. I do not know whether this is correct or not, but as usual, Gold's ideas are very stimulating. Saturn may be similar, in terms of this situation on Jupiter, but I think we must assume that Uranus and Neptune both lack hydrogen and helium. We see evidence for a considerable fractionation of the elements in the forming of the major planets.

Just one satellite of the planets in the solar system has been recorded as having an atmosphere, that is Titan, which has an atmosphere of methane, according to the observations of Kuiper. This is a little difficult to understand, for the photochemistry should be such as to destroy methane, hydrogen should escape from the satellite, and we should expect that by now all of the methane would be condensed on its surface as non-volatile carbon compounds. The escape of hydrogen in the high atmosphere of the Earth is controlled by diffusion and also by condensation at the tropopause. Possibly similar phenomena are operating on Titan to prevent the escape of hydrogen, and hence a certain amount of methane in the gaseous state can remain there for a long, period of time.

CHAIRMAN BERKNER: Dr. Chamberlain, do you want to start now your discussion of the problems of photochemistry in planetary atmospheres, and the methods that one might use to study these atmospheres?

DR. CHAMBERLAIN: The first question that we want to ask, so far as the photochemistry of a planet is concerned, is, of course: 'What are the principal constituents in a planetary atmosphere—the molecular nitrogen, hydrogen, carbon dioxide, and so on?' Theoretically it would be possible to start out from this information, from a knowledge of the solar spectrum, and from first principles, and deduce everything that one needs to know about the photochemistry. In practice this is virtually impossible, for we know very little about reaction rates, photodissociation, and the various factors that modify the relative abundances of the elements as functions of height in a planetary atmosphere.

The question then becomes: 'How much can we observe? What partial information can we obtain observationally which, when combined with a partial theory that we can develop, will provide an idea of what a planetary atmosphere is like as a function of its height?'

The first information beyond knowledge of the basic constituents that one would seek is a knowledge of the dissociation of these constituents. As height increases in the atmosphere, oxygen becomes photodissociated through solar radiation, principally in two spectral regions. In the Earth's atmosphere, for example, the major dissociation occurs in the hundred-kilometer region, the strong Schumann-Runge continuum, above which there is very little molecular oxygen (O_2). The small amount of O_2 which does exist there is present only because it manages to diffuse upward more rapidly than it is dissociated.

Lower in the atmosphere, oxygen is dissociated in the weak Herzberg-absorption continuum.

This absorption gives rise to the ozone layer in the 30–50 kilometer region on the Earth. Other constituents, such as nitrogen and hydrogen, will not be dissociated readily by sunlight, but there are nevertheless indirect means of producing dissociation. If nitrogen becomes dissociated either in the terrestrial or other atmospheres, it does so probably at quite high altitudes (perhaps in the range of 200 kilometers or higher on Earth). The principal mechanism of dissociation involves ionization of N_2 and then recombination of the ion N_2^+, which dissociates into $N + N$.

As we obtain this information on atmospheric dissociation, it becomes important to know the pressures at which these effects occur—the partial pressure, for instance, at which oxygen is being dissociated, and the pressure of the other constituents besides oxygen at the same level. Without this information it becomes very difficult to do any theoretical interpretation at all.

The minor constituents of an atmosphere can also be very important in photochemical studies; examples include the OH radical, ozone, and atomic oxygen which, compared with the total abundance of a planetary atmosphere, are likely to be extremely rare. Knowledge of their existence, and particularly of the height at which they exist, would be of great theoretical value in deducing photochemical processes.

One might secure information on a minor constituent through spectroscopic detection. In principle, these data might even allow a determination of the abundance of a major constituent. A specific example of such an application is the study of the ozone content of the atmosphere of Mars, where it has been used to establish an upper limit on the O_2 abundance; this is a more restrictive limit, actually, than that secured by direct observations of O_2.

Study of these minor constituents, which are photochemically very active, also brings out a whole range of new problems with which we may not be entirely prepared to cope. For example, if some constituent is keeping most of the active solar radiation from reaching the surface, we don't have much of a photochemical problem at the ground. That is, if there is a large abundance of ozone, carbon dioxide or some other molecule which could be dissociated, it may also blanket out a large part of the ultraviolet solar radiation. Suppose, however, that there is a pure oxygen-hydrogen atmosphere, where the oxygen is very rare, as it seems to be on Mars. One might then suppose that a thin ozone layer will occur close to the ground. If the ozone is not strongly absorbing at the ground, then solar radiation would be expected to be very important in dissociating any water vapor.

Without a protective covering, the surface would not contain much free water. However, in the process of water dissociation, some free hydrogen is produced. This hydrogen can react with and destroy the ozone which is present. Hence, the problem becomes one of great complexity. I think, for instance, that in considering the abundance of ozone and its relation to the total free oxygen content on Mars, we have not really given consideration to the details of possible modifying effects of any free hydrogen. Suppose a hydrogen-ozone reaction is going on close to the planet; then we expect to see OH in emission from the night side. We might detect OH in absorption as well, but if it is produced by a photochemical reaction such as I have just proposed, emission might also be detected, and I believe that this is the more exciting possibility.

Many of these experiments on detecting the major, or even the minor, constituents might be done from just outside the Earth's atmosphere. The only real problem is to get beyond the absorption produced by our own atmosphere, and to get enough angular resolution with a telescope to see the planet.

However, some of the most exciting problems actually require going close to the planet—in the case of Mars, for example, of actually getting around to its back side. If reactions such as those I have just discussed are occurring there, they may show up in the night airglow of the planet. Also for both absorption and emission spectra of a planet, we should eventually make an effort to get enough spectral resolution for determining spectroscopic temperatures. These temperatures are valuable in helping to establish the height at which the absorption or the emission originates. Of course, by going to the planet, we can obtain also a type of absorption measurement that is not feasible from studies undertaken close to the Earth. Such measurements require a satellite or a probe grazing by the planet, so that the Sun is just eclipsed, and so

that absorption spectra are obtained through highly resolved layers within the atmosphere. This experiment would help to determine the relative abundance of the elements in the atmosphere as a function of height above the planet.

Besides studies of the night airglow, which would occur principally as the result of photochemical reactions, there is another type of emission spectrum that I think could be a very powerful tool in determining the abundances as a function of height. This experiment involves the narrow twilight zone of a planet and would record the 'twilight airglow.' A large part of the twilight airglow arises as a result of resonance scattering from sunlight by the constitutents in the atmosphere. The fact that it arises in the twilight zones, where the ground is in the shadow produced by the planet, allows one to determine the abundances of the scattering constituent. For example, one could look at the Earth's atmosphere in Lyman-alpha hydrogen light and, from its resonance scattering, deduce the amount of hydrogen that extends for a long distance from the Earth.

Essentially the same type of experiments could be made for atomic oxygen, which has a particular fluorescent process because of a Bowen resonance mechanism. That is, oxygen has a transition from its ground level with the same excitation potential as Lyman-beta, and the Sun produces a strong emission source in Lyman-beta. A look at this oxygen line would provide a very good measure of the atomic oxygen of a planet's atmosphere as a function of height. This experiment can be done to advantage for the Earth, as well as for any of the other planets.

In summary, much may be gained through both absorption and emission ultraviolet studies. I would like to suggest that particular emphasis be given to the emission properties in the twilight, to the night side and, to some extent, to the aurora. We now know that we cannot easily study the aurora and deduce much about the characteristics of the atmosphere. Hence, although auroral studies are valuable for other reasons, the emphasis in studies of atmospheric properties should be made by investigations of the twilight and night airglow.

CHAIRMAN BERKNER: Would you discuss the apparatus needed for these studies and research that may be necessary for developing new experimental devices?

DR. CHAMBERLAIN: As far as the spectroscopic equipment is concerned, there are no basic problems that are not already solved. For the intensities that we can detect and the range of sensitivities in which we are interested, the equipment is feasible. There is, of course, still a matter of engineering development to extend and modify present rocket instrumentation.

DR. UREY: Based on what we know now, what, in your opinion, is the temperature in the high atmosphere of the Earth?

DR. CHAMBERLAIN: Fifteen hundred or two thousand degrees.

DR. UREY: You limit it to two thousand degrees? You do not think it would be three or four thousand?

DR. CHAMBERLAIN: You are asking for a probable error in my guess? I would be very surprised if it were as much as one thousand degrees higher.

DR. UREY: Do you have any idea as to the high temperature of the atmosphere of Mars?

DR. CHAMBERLAIN: No. The question of the temperature in the very high atmosphere is related more to the question of the ionization of the planet's atmosphere than to its photochemistry. Ionization is the process producing the high temperature. I shall have something to say on this subject in the third discussion of the agenda, but it is very difficult to make a good estimate.

DR. UREY: I asked the question for this reason: If the temperature is two thousand degrees at the escape layer of Mars, oxygen will escape at an appreciable rate. The escape layer would be very high because of the high gravitational field, and the escape of oxygen atoms would be appreciable. This means, of course, that both oxygen and hydrogen can escape, which will destroy water. It is very difficult to understand how life as we know it on Earth evolved on Mars, except in the presence of oceans. It seems as though there would be no oceans on Mars at the present time if oxygen is escaping at an appreciable rate.

CHAIRMAN BERKNER: The biologists, of course, are intensely interested in what part of the solar spectrum eventually reaches the surface of the planets. You discussed possible reactions in ultraviolet light, but is it possible that very

short wave lengths of ultraviolet do reach the surface of Mars, for example? If the question can't be answered from what we now know, then it seems very important to secure this information as quickly as possible, even before landing on Mars. Could you comment on that?

DR. CHAMBERLAIN: This is a matter associated directly with the photochemistry of the planet, and certainly we want to make ultraviolet spectral studies of the surface. However, I think the experiments I have proposed are directly associated with just that problem. Sometimes we talk about how much ultraviolet reaches the surface. People say, 'Well, it can't, because there is a haze on Mars, and we can't see the surface.' But an observer on the surface of Mars could certainly see plenty of sunlight even if it is scattered very strongly. So it is not so much the question 'Is there any haze, any scattering?' but, rather, 'Is there any true absorption caused by a photochemical reaction, such as the dissociation of ozone?'

DR. HINTEREGGER: I would like to say a few words on the instrumental problem of detecting extreme ultraviolet from the Sun. I have prepared a circular entitled 'Exploration of the Ionosphere by Telemetering Monochromators and Retarding Potential Analyzers' which deals mainly with our recent measurements of solar radiation fluxes in the important wave length range between 1300 and 60 A. These measurements were made from rockets up to altitudes of 225 km.

Even above 200 km, the absorption by the terrestrial atmosphere is very significant in many important wave lengths that are able to ionize all atmospheric constituents. Also, the heating of the atmosphere above 200 km—for instance, in the hydrogen Lyman-gamma line—could be contributing strongly to a higher upper atmospheric temperature than is generally believed. What reaches the surface of the planet, of course, depends on atmospheric composition considered in conjunction with the solar radiation.

We can now, with non-photographic means, make direct measurements of dispersed solar radiation intensities. Accuracy and useful sensitivity are improving rapidly. In January 1960, on an Aerobee Hi rocket the background counting rate was so low that the accuracy was actually limited by the statistical fluctuations in the dispersed photon flux. I think it will be possible in the very near future to adapt existing techniques to satellite experiments and thus give us very significant clues for future experiments near other planets.

DR. FRIEDMAN: I would like to draw attention to a relatively simple way to look at the hydrogen and oxygen. Dr. Chamberlain has already mentioned the hydrogen problem, where you look at Lyman-alpha. This can be done with a photoelectric detector, without a spectrograph.

You can also see oxygen. Dr. Chamberlain mentioned the resonance with the Lyman-beta line, but there is a resonance at 1300 angstroms. We have been able to show that, in the night sky, you can see this airglow with a detector that covers a band from 1280 to 1350 angstroms, and you do not see it in the bands of 1380 to 1500 angstroms. At least for these two constituents, relatively simple instrumentation is available.

CHAIRMAN BERKNER: Let's turn to the problem of atmospheric constituents. Dr. de Vaucouleurs, would you start the discussion?

DR. DE VAUCOULEURS: In a discussion of the atmospheres of Mercury, Venus and Mars we want to know their composition, their mass, their temperature, their pressure, and then turn to specific details of meteorology and so on.

The atmosphere of Mercury must be made up of rare gases, probably heavier than argon. It has to be krypton or xenon, and only a little would be available. How much, is very difficult to say.

In the case of Mars, which comes next in its ability to retain an atmosphere, we have good evidence that there is carbon dioxide, but the exact amount of it is still very much in doubt. The present figure is something like 40 meters NTP of carbon dioxide. We suspect that there must be some argon for the same reason that there is argon on Earth, and this might be of the order of 70 meters NTP. We believe that there is less than two meters of oxygen.

We know the total mass of the atmosphere of Mars. The pressure on Mars has been determined by photometric and polarimetric methods, taking all necessary precautions against particle scattering and so on, and the results are in good agreement. The pressure on the surface of Mars appears to be of the order of 80 or 85 millibars; it would be extremely surprising if this figure

could be wrong by as much as 50 per cent. Hence, there must be a large amount of gas which we do not see, and the only plausible possibility is nitrogen; the amount required is 1650 meters NTP.

We know that there must be traces of water vapor because we see the ice on the surface, but the amount of water vapor in the atmosphere is too small to be detected spectroscopically. We all hope that Dr. Strong and his group will be able to detect it at the next opposition.

One important characteristic of the spectrum of Mars is its very low albedo in the near ultraviolet. Between three and four thousand angstroms Mars is not red, but gray, and the albedo is about 0.045. This is a well-determined figure. It is generally believed that there is a reflecting layer of some kind, maybe a haze of ice crystals, in the atmosphere of Mars. If we fit the data in the blue by Mie scattering particles, we would expect an increased reflectivity in the ultraviolet, whereas in fact we observe a very much lower reflectivity.

It seems to me that we must accept the idea of a strong atmospheric absorption band in the near ultraviolet; if so, the haze can reflect more greatly in the ultraviolet than in the blue but we are looking at it through a dark filter. (Dr. Kiess has suggested that the substance might be N_2O_4.)

One result obtained by a rocket measurement at 2740 angstroms again suggests a high albedo. I understand that the observations were marginal, and whether we should accept them or not is not known, but we do know now that there is no increase of reflectivity down to 3200 angstroms.

Regarding Venus, we know that there is about one kilometer NTP of carbon dioxide above the cloud level. We should keep in mind that this figure is uncertain by a factor of about two. Now, there are a number of ways of estimating the total mass of gas above the top of the cloud. Each is admittedly uncertain. However, they all agree within a factor of two and give a pressure of just about 160 or 170 millibars at the top of the cloud. The fact that we can account for this 160 or 170 millibars by carbon dioxide alone (which is given by spectroscopic observations, whereas the others are based on polarimetry and photometry) suggests that there is little nitrogen. In other words, it would be extremely surprising if the atmosphere of Venus were 90 per cent nitrogen and 10 per cent carbon dioxide above the cloud level. I find it difficult to believe that there could be more than, say, 50 per cent nitrogen in the atmosphere, but there could be considerably less. So the mean molecular mass must be between 44 and 36.

Again, and for the same reason as for the Earth and Mars, there might be something like 70 meters NTP of argon above the surface. We know that there is less than about 30 meters of oxygen but the tests for oxygen on Venus have not been very extensive. Strong and his group have detected a very small amount of water vapor above the clouds; the figure is of the order of 19 microns of precipitable water, admittedly with a large uncertainty.

Again, we observe that Venus, although exceedingly bright in the visible part of the spectrum, is surprisingly dark in the ultraviolet. The basic astronomical observation by Kozyrev is weak and it should be repeated. Nevertheless, we know that the albedo in the ultraviolet may be as low as 10 to 20 per cent, and that is is 70 to 80 per cent in the red. So here again we have an indication of absorption which, in the case of Venus, begins very sharply at 4500 angstroms.

In this connection I would like to make a comment about the cloud cover on Venus. The argument has been made that Venus is yellowish, more so than the Sun, and that consequently the clouds are made up of yellow crystals. I cannot agree with this. A large part of the effect is due to the strong absorption which begins at 4500 angstroms. Trying to guess at the chemical composition of the clouds from the over-all color of Venus is certainly unwarranted.

Now, consider the question of the mass of the atmosphere of Venus. From the ordinary optical range up to at least several microns, we can see down to the cloud level or levels. We would like to know what the surface pressure is; therefore, we need to know the altitude of the top of the clouds. We have a good idea of the scale height and, if we knew the altitude of the cloud, we could work out the surface pressure. However, before I become involved in a discussion of atmospheric temperatures, I wish to call on Dr. Sinton to give us the radiometric evidence.

DR. SINTON: We have had radiometric temper-

ature measurements of the planets, obtained by Pettit and Nicholson and Coblentz and Lampland, for almost forty years. Recent work by Dr. Strong and myself has largely confirmed earlier measurements.

I will consider Venus first. In the band in which one can observe (between eight and thirteen microns) we are sure that we are measuring temperature somewhere within the atmosphere of Venus, because nearly the same temperature has been obtained during the Venus night—that is, on the dark part of the disk—as during the sunlit part. This temperature is about minus 40 degrees centigrade. I am using the data of Pettit and Nicholson on a number of nights between 1924 and 1927, and the observations by Strong and myself, which have extended over seven or eight years.

There was some indication in Coblentz and Lampland's measurements that this temperature was quite variable and went up to as much as 60° C. I, personally, have not seen this, but Coblentz and Lampland made a great many measurements. Most of these have not been published or reduced, but I hope they can be reduced this summer so that we will have the advantage of all of their temperature measurements.

A temperature of 12° was determined by Chamberlain and Kuiper from an analysis of the intensity distribution within the CO_2 vibration rotation bands level. This applies to a region slightly above the top of the cloud layer. The probable error is 9° C. The actual temperature cannot agree with the radiometric temperature, because of the presence of spectral lines having very high rotational energies. That is, for a low temperature, the rotational levels giving rise to these lines would not be significantly populated. A radio temperature of the order of 300 degrees centigrade is now well established, and apparently applies to the surface.

One may develop an atmospheric model by assuming an adiabatic lapse rate of 10 degrees per kilometer and from this establish the altitude of the top of the cloud level. This gives 27 kilometers for the height of the cloud level.

The radiometric temperature applies to a level somewhat higher than the clouds. Radiometry has been performed over the disk of Venus, whereas the other temperatures apply more or less to the disk as a whole. From the radiometry we have well established limb-darkening, which, however, has not been observed with sufficient accuracy to allow us to distinguish between a gray and a non-gray atmosphere. An atmosphere in radiative equilibrium, with either gray absorption or absorption by lines, will fit the observations equally well.

Of course, we do not know the period of rotation of Venus. It appears to me that its equivalence with the period of revolution is not acceptable. The north and south limb temperatures are significantly below the temperatures of the east and west limb. Therefore, there is a symmetry to the planet imposed by rotation about an axis that is more or less at right angles to its orbit. The ultraviolet cloud pictures also seem to indicate this.

The night radiometric temperature is perhaps a few degrees cooler than the day side, but this is somewhat questionable. It may even be equal. Within the accuracy of the observations, it could be warmer.

In the case of Mars, primarily we have temperatures of the surface by radiometric observations. As Dr. Chamberlain mentioned, it would be very nice to have a spectroscopic temperature such as that from the CO_2 bands on Venus. Such a temperature could be obtained by considerably higher resolution of the Martian carbon dioxide bands than has been obtained heretofore, but this will be difficult to obtain.

The maximum temperature of the surface at the equator of Mars is about 30 degrees centigrade, and the nighttime temperature at the equator is of the order of minus 70 degrees. There is also evidence from the observations of bands of CO_2 that there is a normal lapse rate in the ten-micron region. The bands appear in absorption and indicate that the atmosphere is colder than the surface. We might assume that the normal adiabatic lapse rate of 3.7°C/km applies in the absence of significant amounts of water vapor.

Dr. de Vaucouleurs: We know fairly well the surface temperatures on Mars but we have little more than theoretical ideas as to the temperature of the atmosphere. We have not been able to define, theoretically, what is supposed to happen in the atmosphere of Mars. Estimates of the depth of the convection range

from less than 10 to 30 to almost a hundred kilometers. We can only guess that there is a lapse rate of about three and a half degrees per kilometer near the surface. What happens above the surface depends very much on the distribution of carbon dioxide and of water vapor which we know to be present but cannot observe.

However, for the sake of argument, if we assume that the mean temperature of the lower atmosphere of Mars is about 220° K, then the computed mean scale height in the lower atmosphere is about 18 kilometers. Starting from the known surface pressure, this means that the pressure in the atmosphere of Mars is the same as the pressure in the atmosphere of Earth at about 28–30 kilometers. Above this level the pressure in the upper atmosphere of Mars is bound to be very much higher than in our own atmosphere.

It would, of course, be interesting to know the pressures at 100 to 200 kilometers above the surface of Mars. This could be discovered very easily if we had real support for planetary observations from the surface of the Earth, or from balloons, but up to now it has proved difficult to secure support for this kind of space exploration. This information can be obtained any time we decide to get it and probably within a very few years. We have the techniques, but they have not yet been applied to studies of the Martian atmosphere.

For Venus we have more information. In summary, we accept a surface temperature of 580° K and a temperature of about 285° K near the top of the cloud. As noted by Dr. Sinton, the radiometric temperature in the eight to fourteen microns band is about 230 or 240° K, which, I suppose, refers to an altitude of roughly 40 to 45 kilometers above the clouds. The reason for this conclusion is that, in those wave length bands of the transparent window where we receive radiation from the carbon dioxide, such radiation cannot come from the top of the cloud because the optical depth is too large. It must come from a region where the total amount of carbon dioxide above this level is only of the order of one meter. A question may be raised here: why is it, then, that we do not observe higher temperatures between the carbon dioxide bands? The answer to this question is not known, but the fact is that the radiation in the 8 to 14 micron window is nearly isothermal.

Finally, we have an additional piece of information, which has come from the observation of the occultation of Regulus by Venus. Photoelectric observations of the fading rate at ingress due to differential refraction in the upper atmosphere gave a figure for the scale height, $H = 6.8$ kilometers; and for its first derivative, $1/H \times \delta H/\delta Z$, of one per cent per kilometer. If we accept the mean molar mass as 42.5, this implies a temperature of 297° K (with a probable error of 10°) and a temperature gradient of plus 3 degrees per kilometer. The region probed was about 70 kilometers above the top of the cloud layer.

If we consider all these data together, we can construct a picture in which the top of the cloud layer is around 27 kilometers above the surface, where the radiometric temperature is measured in a region about 70 kilometers above the surface, and where the occultation region is about 95 to 100 kilometers above the surface.

We also have two points for the pressure. We have the pressure at the top of the clouds which is, as I have said, about 160–170 millibars; we have also, from the occultation data, the pressure at the corresponding level, 2.6 dynes per square centimeter. Now, these two points can be connected through the temperature curve, and we find a theoretical altitude difference of 65 kilometers. Observationally we found 70 kilometers plus or minus 8. So it appears that we have a general idea of the pressure and temperature curves in the atmosphere of Venus.

If we use this model, it gives two to three atmospheres at the surface although the uncertainty may be a factor of three either way; in other words, the surface pressure might be between one and ten atmospheres. I cannot very well believe that the surface pressure may be as high as a hundred or a thousand atmospheres, as was suggested recently, but a few atmospheres seems plausible. If so, this means that, even if there is water vapor in the lower atmosphere, because of the high temperature and the modest pressure, there cannot be liquid water at the surface. Condensation of the clouds will take place at an altitude of the order of 20 kilometers. Meteorologists could try to work this out more precisely.

As you know, the field of planetary observations has been left, by and large, to a few isolated experiments by physicists and to irregular patrol work by amateurs. Much more could be done once we decide to do it. As far as a whole program is concerned, there are a great many questions that can be raised, a great many experiments which could be undertaken. Some have been described already in previous reports of this Board. Some new techniques should be considered, such as interference spectroscopy by the Fourier transforms method, which was used in studies of the airglow on Earth. This could be tried out from the Earth very easily, and the equivalent could be adapted for use in a probe. How this equipment would stand high acceleration is another question, but there is no basic difficulty.

There are also other problems such as the clearing of the blue haze on Mars near opposition. I should like to make it quite clear that this blue haze conceals the surface, not because it is opaque, but because of its back-scattering. It is very thin, so the answer to a previously raised question, is that certainly a large fraction of the near ultraviolet solar radiation between three and four thousand angstroms penetrates to the surface, reduced by whatever true molecular absorptions exists in this region. There is evidence that this blue clearing occurs selectively near opposition, although not exclusively. There are well established cases of blue clearing several months away from opposition, but it remains true that, even when this is taken into account, there is strong indication that the blue clearing occurs more frequently, and more extensively, near opposition. Now, if this involves some kind of solar-terrestrial planetary relationship due to geometry, or to magnetic effects of the Earth, a control experiment could be done from a space probe flying near Mars and photographing it in the blue, at several Sun–probe–Mars angles.

Also, as I think Dr. Chamberlain has mentioned, we would like to observe the scattering by Mars at large phase angles. The maximum phase angle from the Earth is 47 or 48 degrees, and we cannot make a meaningful study of scattering unless we have a complete phase curve.

Finally, we could obtain more information if we would observe these planets carefully from the Earth or from balloons; there are several methods which are available and which could be applied. However, I believe it is rather late; other questions can be discussed later.

The morning session adjourned at this point.

Afternoon Session

Chairman Berkner: A number of experiments have been mentioned that could be done both from the Earth or from the vicinity of the Earth, and in the vicinity of the planets. The Board is vitally interested in whether or not the required instrumentation is being planned or is available.

Dr. de Vaucouleurs: One conclusion that seems to have emerged from many discussions and private conversations is: as planetary astronomers we do not see any great advantage in doing planetary astronomy from Earth satellites. The advantage of being able to observe the ultraviolet can be used, of course, but that is a relatively small thing in planetary studies. The basic obstacles to obtaining further knowledge of the planets are the turbulence and infrared absorption of the Earth's atmosphere, and we must carry our instruments above those. The best way to do this is, of course, to use balloons, because with a balloon it is possible to raise a 40 or 60-inch telescope, if needed, and to get the equipment back and make more observations. It is difficult to visualize throwing 60-inch telescopes into space one after the other; also, recovery of the information is more difficult.

With three 36-inch telescopes, one flying, another being used to prepare new experiments, and the third being repaired from slight damage of landing, or on standby, one could observe the planets possibly for 300 days a year from the southwest. In terms of the space program this approach represents a minor expenditure. The one limitation of balloons is, of course, the vacuum ultraviolet which, unless I am mistaken, is of relatively little significance for planetary astronomy, although of great interest for upper atmosphere physics.

The other way in which significant research progress can be achieved is by use of space probes. In between, the orbital telescope is of little advantage—the planets are still one hundred million miles away, and this is the

basic obstacle. It seems much better, to me, to send a 2-inch camera within a thousand miles of Mars than to try to place a very large telescope in orbit around the Earth.

Basically the equipment and techniques to observe from balloons are now known, although some engineering is still needed to perfect techniques of guidance. So far as instrumentation of space probes is concerned, astronomers are not particularly qualified to determine what sort of equipment should be designed.

DR. SINTON: I would like to point out that planetary studies are really time phenomena. One cannot get the full story from just a glance. This speaks strongly in favor of further ground-based observations, and balloon-based observations.

DR. DE VAUCOULEURS: This is a point I failed to bring out. If we could have a ground network of telescopes for the study of the planets, similar to that achieved by solar astronomers, then we could obtain the information with existing techniques, within the time it takes to develop the information, perhaps a few years.

Potentially, we also have the published observations of the past. For instance, we have records of the behavior of the polar caps of Mars for something like 80 years—seven solar cycles. If there are good reasons to extract this information we can do it fairly quickly. It seems to me that the solution to some of our problems is in cooperation between the few astronomers and geophysicists who have a common interest.

DR. UREY: I should like to make a remark about N_2O_4 in the atmosphere of planets. This is an unstable substance, and it will decompose spontaneously into N_2 and O_2, if given sufficient time. It is always in equilibrium with NO_2.

If unstable compounds are present in the atmosphere of the planets, for examples, N_2O and hydrogen or ozone, we can make the assumption that the total pressure of N_2O_4 and N_2O_3 in the atmosphere of these planets is a millionth of an atmosphere. My calculations, if I have made no mistake, mean that only one millionth of the nitrogen would be present as N_2O_4; that is, 10^{-13} would be the concentration of N_2O_4. The idea that the surface of Mars is covered with snowdrifts of N_2O_4, is, I think fantastic. Also N_2O_4 reacts very readily with carbon compounds, and the atmosphere of Venus contains both methane and ammonia. Compounds of ammonia and the oxides of nitrogen are very good detonating agents; they will explode under proper conditions. So I would like to emphasize that this N_2O_4 business, to my mind, is exceedingly doubtful.

DR. KELLOGG: I would like to pose a question. Suppose we did have an active balloon astronomy program, with 36-inch telescopes floating at 80,000 feet or so. By how much would we improve the resolution of planetary observations?

DR. DE VAUCOULEURS: You would have one hundred per cent observing time. Resolution would be limited by diffraction. This means that, with a 36-inch telescope, you would easily see photographic details one-tenth of a second in diameter all of the time. As a rule-of-thumb we can say that this means an increase of resolution by a factor of 4, which in number of information elements is 16, and should be compounded with the time factor of 30 to 100. This makes a tremendous difference.

DR. KELLOGG: The question is, do we really improve with balloon astronomy, and if we can do a lot more from balloon astronomy, are some things still left to be done at still closer distances? We can never see the dark side of Mars from the Earth. Can we think of some other things that we can't do, even from a balloon observatory?

DR. DE VAUCOULEURS: We have recently gone through all these questions very throughly, and it is difficult to summarize the whole of planetary astronomy in a few minutes. However, one might say that from the ground you cannot do very much more than we have already done, except for continuous synoptic observations where the crucial factor is time. If you want to make very significant progress—measured, say, by a factor of 10—you need a medium-sized telescope, or rather three of them to keep going. Some development is involved, because we still have to learn how to use a telescope from a balloon on a routine basis. But, given a little push, this program could advance planetary astronomy a great deal.

You have referred to the number of picture elements in ordinary photographs, which you consider, with reason, as disappointing. You have between 100 and 1000 picture elements in the area of the planet, but we know that from

balloons we could have 10,000 all of the time. If we could have a ten-fold increase of pictures we could do the whole of planetary astronomy all over again. However, this would still be from an earth-based station, and the planets would still be millions of miles away. You would not be able to gain still another factor of 10 in resolution simply because we cannot build a thousand-inch reflector, and even if we could, it would be still a fractional gain.

So, if you want to see details that are smaller than, say 20 kilometers, you have to go close to the planets and use a small instrument for a real close-up. For instance, a standard air reconnaissance 7-inch focus lens, giving a resolution of 30 lines per millimeter for unit contrast targets placed at a distance of, say, 1000 to 10,000 kilometers from Mars, would give a resolution of the order of one kilometer or better. So you would have a gain of almost two orders of magnitude beyond any Earth-based telescope, or even from balloons. In other words, for really fine detail, looking for significant structures that we can identify, we must go close; this is where the space probe cannot be replaced.

Another point that should, perhaps, be made here. Suppose you send a probe with a well designed experiment, and you receive back pictures which are blank. You would want to know what is going on. What has happened to your probe? Have you been photographing the top of a dust cloud? This is where the ground observations, backed up by at least one balloon station, will help you. Then you will be able to take photographic or radiometric observations of the area that is going to be photographed from the probe in order to see whether it is covered with cloud.

Suppose we send in a probe with an infrared spectrometer that would repeat, with high lateral resolution, what Dr. Sinton has done for the infrared spectrum of the dark regions of Mars. We will want to look at the small details of the surface, not only for checking work conducted from the Earth, but especially to take a better look at the small details and to see whether this infrared spectrum changes with the seasons.

Then we must determine whether the seasonal darkening wave has reached the region observed or not; whether it is in a quiescent stage, is actively developing, and so on. In brief, we need to patrol the planets, not as a substitute for a space program, but to interpret the data when we get them back.

CHAIRMAN BERKNER: There is another point that should be made here: any advance information that one can get concerning the atmosphere would influence the design of experiments, let's say in the field of biology, or in many areas of scientific activity.

DR. JASTROW: I would like to go on record as being in complete disagreement with the most recent part of this discussion. I think that we have lost sight of those properties of the atmosphere— the pressure at the surface and the composition—that are truly fundamental, and that we must determine first before we get down to such details as a latitude variation over the surface, which one could get from the resolution of a close space probe. The space probe gives us the opportunity of sending a daughter probe down through that atmosphere to the surface, with a very simple package of mass spectrometers, pressure gauges, and an ion trap to measure ionization levels. These are the things that we have to do first. They are things that provide information that one does not get from ultraviolet spectroscopy, whether it is done from the planet or from a balloon, and they are fundamental properties on which to concentrate. I thought I detected in this discussion a statement that it is primarily a question of resolution that distinguishes balloon observations or satellite observations from planetary probe observations. I don't think that that is a correct statement of the problem. Both the balloon and the planetary probe observations of, let us say, the ultraviolet spectrum, still give us a picture only of certain conditions on top of the atmosphere; however, what the planetary probe will do for the first phase of the program is to give us the profile of the atmosphere in a rough way, averaged over a latitude, right down to the surface, that is, the fundamental facts that we need to know about all atmospheres.

DR. HIBBS: Dr. Jastrow has referred to sending a probe through the atmosphere to the surface as a first phase in the planetary program. I wonder if he has an idea of the time schedule for that experiment, say for Mars?

DR. JASTROW: What is behind your question

is the feeling that a probe to the surface may be a difficult thing to do, which is something I think is to be discussed. But, when one considers putting the effort into such a project, as compared with putting effort into, for example, ultraviolet spectroscopy on a probe going by the planet, and when one considers that everything can be done in ultraviolet spectroscopy from a balloon except for the loss of resolution over the face of the planet, then at this stage of our knowledge of planetary atmospheres a gain of resolution and latitude dependence over the face of the planet is not very important.

DR. HIBBS: The same thing can be said of the weather on the Earth. We have only now been able to measure a few thousand miles with Tiros I. Heretofore, we have had a different point of view when looking at our planet's atmosphere, but we have a somewhat different position with respect to the planetary atmospheres. We are looking from the outside, in. Should we not now begin to look at the nature of the problem, not from the traditional point of view of what we have always done on Earth, but from the particular point of view of what is to be gained.

Dr. Chamberlain pointed out that the ionization charges cause heating of the upper atmosphere. We must get the fundamental information about planetary atmospheres as we have gotten it from the Earth, in our case by going from the surface up, but in the case of the planets from the outside in, before we begin to understand the dynamics of the atmospheres and how the conditions for life may differ.

DR. SINTON: You are saying what you would like to do first, but we are limited instrumentation-wise, and can only do what can be done first—namely, the balloon observations. The temperature profile and pressure and composition measurements are fundamental, of course, when they become possible.

DR. JASTROW: The purpose of my remarks was only to raise again the question of the directions in which we should point our study of planetary atmospheres. I am quite in agreement with you that more can and should be done from the Earth and from balloons.

DR. UREY: I believe all of these points of view are correct, and that there is no disagreement. We should have high balloons to learn all we can, and we should push our space probe program. We are merely presenting different parts of a program that will be separated from each other in time.

DR. KELLOGG: A step has been left out. Knowing the complexity and difficulty of making a spacecraft that will have daughter spacecrafts and enter into an atmosphere, as Dr. Jastrow suggests, it seems to me that the first step is a fly-by. In fact, the first several trips to the planets may be just fly-bys incapable of sending instrumentation into the atmosphere. I can think of one experiment that you can't do from a balloon, but that requires entering the atmosphere. It is the combination of radar and optical measurements of Venus to determine the depth of the cloud layer. It seems to me this is very fundamental.

DR. ESHLEMAN: I would like to comment on ground-based radar measurements of the ionized part of planetary atmospheres and on measurements of planetary surfaces and rotations. I am confident that the experimenters who now have large radar systems in operation will make some of these measurements in the near future. Concerning the resolution that can be obtained on planetary surfaces and atmospheres, the optical astronomers want to get above the atmosphere for high resolution but there is no such fundamental limitation in the use of radar. Radar resolution of the surfaces of the planets is limited only by our willingness to spend money for transmitters and antennas.

DR. LITTLE: I feel sure that you agree that radio astronomy in the receiving sense as well as the radar astronomy sense, could be expanded readily. Land-based radio astronomy measurements of the planets are not yet, to my mind, supported adequately. Many experiments could be undertaken, at relatively low cost, that would undoubtedly increase our knowledge of the planetary atmospheres.

CHAIRMAN BERKNER: What is the present prospect with regard to good spectrometry of the atmospheres of the planets?

DR. INGHRAM: Just as there are numbers of distinct types of instruments which are used in optical spectroscopy, so also there are a number of distinct types of instruments used in mass spectrometry. There are instruments for working with materials that are normally solids; there are instruments for looking at the absorbed species on solid surfaces; and there are instru-

ments for study of gases. Since our interest here is planetary atmospheres I will confine my remarks to the last category.

Two problems regarding the use of mass spectrometry for the study of planetary atmospheres deserve comment. First, there is the problem of the type of instrument to be used. Second, there is the problem of getting top research people into the field.

A very common misconception is that the only type of mass spectrometer suitable for the space program is a radiofrequency (RF) type—that the standard magnetic deflection type of instrument is not usable. That such a misconception can arise is easily understandable, because, if one goes into a laboratory where there are standard analytical mass spectrometers, one sees a large instrument with a relatively large magnet. By contrast most RF instruments are small and have no magnet. However, one cannot conclude from this that the RF instruments are superior for space work. The danger lies in comparing instruments with widely differing resolving powers and sensitivities. When RF and magnetic deflection instruments of comparable resolving power and sensitivity are compared for use in space research, the differences almost completely disappear.

Some time ago, we held a meeting in Chicago at which we brought together about 20 people who were active in, or could contribute to, mass spectrometer programs for space research. The group included those active in the development of RF equipment as well as those active in the development of magnetic deflection instruments. This group concluded that, considering weight and size, no important differences exist between the two types of instruments.

Another factor that should have some influence on the type of instrument to be used is reliability. The standard magnetic deflection type of instrument is well understood. The results are reliable. Those laboratories that have tried to use RF instruments to replace magnetic deflection instruments have generally found them considerably less reliable. It seems to me that the large amount of money spent in flying RF instruments of questionable reliability could be spent better if a much larger fraction were used for laboratory evaluation and development of those RF instruments. In addition I feel that we must also fly the more reliable magnetic deflection type of instrument.

I now wish to speak for a moment on the problem of adequate staff for the mass spectrometry part of the space program. There is a big difference between attracting a top 'mass spectroscopist' into the space program as compared to, for example, attracting a top man in cosmic rays. A scientist interested in cosmic rays can secure more complete and better data if he can get outside the Earth's magnetic field by using rockets. He is, therefore, anxious to extend his basic field of interest by also capitalizing on the space research opportunities. By contrast, the types of information that the mass spectroscopist can obtain on the planetary atmospheres usually involves a complete change in his field of interest since the majority of those who might be called mass spectroscopists are at present using the instrument in very different fields. The difference can also be illustrated by the fact that one name involves the study of a subject and the other an instrument. What is needed is a scientist interested in atmospheric physics who is also a 'mass spectroscopist'. Such individuals are rare, and strong encouragement needs to be given to those top 'mass spectroscopists' who do express an interest in this program.

Finally I would like to make a few comments about what can be done experimentally. The instruments can measure the composition of the neutral species in a gas as soon as the partial pressure of that species gets above about 10 to 12 millimeters. The instruments can determine the cosmic species if they are above about an ion per liter. These figures are somewhat variable depending on the velocity of the probe. The instruments can determine the degree of dissociation of such things as H_2, N_2, O_2, and others. I do not doubt that, with proper support, mass spectrometry can contribute strongly to the understanding of planetary atmospheres.

DR. NIER: I should like to second what Dr. Inghram has said. There has been a prejudice against magnetic type instruments, and my own experience is that the RF instrumentation approach is very appealing; certainly there has been good work of a qualitative sort. But, if you wish to start quantitative work, you must do more sophisticated experiments.

The new mass spectrometers will not weigh

more; they may even weigh less than RF equipment for equivalent performance. One of the serious problems in sampling planetary atmospheres is that of sampling at a high speed through the atmosphere and getting a truly representative sample. The work in this country, such as that of the Naval Research Laboratory, has been very satisfactory in a qualitative way. When you try to make it more quantitative the quality of the sampling comes in. When the equipment is moving in the wrong direction you get a pumping effect, so that the matter of getting samples is a problem. If people apply themselves a great deal of progress can be made, and the techniques are at hand among those who have worked in the laboratory.

CHAIRMAN BERKNER: Dr. Spitzer, I wonder if you want to comment before we leave the subject.

DR. SPITZER: At Princeton we have been giving thought to the observations that one could make with an ultraviolet satellite telescope in orbit around the Earth. We have planned such a telescope, and presumably it will be launched within a period of, perhaps, five years. Considerable research on planetary atmospheres could be done with a device of this sort. I have not made any actual computations of how big a photon count we would get from the different planets but, in principle, one could hope to measure the spectrum of the reflected or scattered light from a number of planets in the ultraviolet at wave lengths shorter than three thousand angstroms.

For example, the spectrum of the Moon might give very valuable indications of the possible presence of a lunar atmosphere. One would measure the intensity of radiation at wave lengths close to a resonant line of one of the heavier gases. If as many as 10^{13} atoms per square centimeter column are in the line of sight, then the albedo of the Moon should be rather high at the line center as a result of atomic scattering; an angstrom or so away the albedo should be quite low, corresponding to reflections from the solid surface.

Hence, if there is an atmosphere of this amount, 10^{13} atoms per cm^3 of a particular type, one would expect to see an emission line in the spectrum of the Moon. I believe this would be a quite sensitive test for the presence of an atmosphere of heavy gases. This method would be less sensitive than if instruments were placed on the surface of the Moon, but it would be a lot easier, and we will have this spectroscopic equipment available, anyway.

Similar experiments could be done on the various planets. Particularly, I would expect that the presence of oxygen on Mars could be detected quite sensitively by looking at possible scattering from the resonant lines of atomic oxygen. It is also possible to obtain the same result by looking for infrared absorption lines, either from a balloon or from a satellite.

Another possibility is to look at the spectrum of the dark sides of the planets and to detect the emission spectrum produced by recombination, as in the night sky of the Earth. Two problems are involved in detecting such radiation. One of them is the very low intensity, which means that a long time elapses before many photons can be counted.

The second problem is the background radiation, mostly scattered light from other sources. In visible light this second difficulty is particularly acute because of the intense sunlight reflected from other parts of the planet. However, this difficulty should be less serious in the ultraviolet. The number of photons emitted in the ultraviolet will probably be comparable to the number of photons emitted in the visible—that is, the atom emits a visible photon at about the same time as it emits an ultraviolet photon, so the intensity should be comparable. On the other hand, the intensity of the sunlight that is scattered by the planet should be less, by many orders of magnitude, in the ultraviolet than in the visible. Therefore, one might hope that the detection of the ultraviolet emission spectra from the dark side of Venus, and possibly even of Mars, would be an easier task than it would be in the visible.

From the spectrum of the major planets, if there is enough reflected intensity in the ultraviolet—and I am not sure that there is—one could hope to measure the abundance of hydrogen and other elements directly from the ultraviolet lines.

These are just a few of the planetary research programs that should be possible once an ultraviolet spectroscopic telescope is placed into orbit.

CHAIRMAN BERKNER: I think we should turn now to a discussion of how one examines the dynamics of the atmospheres. I will ask Dr.

Mintz to begin discussion of this subject.

DR. MINTZ: I believe I can best give you an idea of how dynamic theory may be applied to the study of planetary atmospheres by describing a simple experiment on general circulation.

Imagine that we have a thin layer of gas gravitationally held to a rotating sphere, that the gas is everywhere initially at rest relative to the sphere, and that it is initially at a constant temperature. Let a beam of parallel radiation fall upon this system with the direction of the beam normal to the axis of rotation of the sphere. If either directly or indirectly the gas absorbs the energy of the incident radiative beam, but by radiative loss its mean temperature remains unchanged, a net heating of the envelope of gas at its equator and cooling at the poles of rotation will result.

The gradient of heating from equator to pole will produce a direct meridional circulation in the gas, with ascending motion at the equator, descending motion at the poles, a poleward directed flow in the upper levels, and an equatorward directed flow near the surface of the sphere. At the same time, because of the rotation of the system, the gas will acquire a zonal component of motion relative to the sphere, with the direction of the relative flow being the same as that of the sphere in the upper levels, and opposite near the surface. The magnitude of the vertical shear of the zonal flow will be proportional to the horizontal poleward temperature gradient that has been established in the gas.

Now it can be shown that, depending upon the rotation rate of the sphere and the vertical thickness of the gaseous envelope, there will be a dynamically critical upper limit to the poleward temperature gradient that can be established in the gas by the external heating. If the critical poleward temperature is reached, the flow will change abruptly from the symmetrical circumpolar vortex into a planetary wave-regime. The northward directed branch of each horizontal wave will have a higher temperature than its southward directed branch at the same latitude, and this very efficient horizontal poleward 'eddy-transport' of heat by the waves will prevent any further significant build up of the temperature gradient by the incident radiation. In this way planetary waves limit the size of the poleward temperature gradient, just as small scale convection limits the size of the vertical temperature gradient that can be established by radiation.

The question we would now like to answer is whether or not, in the atmosphere of any particular planet, the poleward temperature gradient produced by radiation has reached the critical limit for baroclinic instability and the growth of planetary waves. The answer to this question depends on the radiative properties of the particular atmosphere, the vertical depth of the atmosphere, and the rotation rate of the planet.

In the Earth's atmosphere the radiation from atmosphere to space comes principally from the water vapor. With the constant upward diffusion of water vapor from the ocean source, the air in all latitudes has a high relative humidity and, as a result, the local water vapor density depends mainly on the air temperature. Near the equator, where the temperature is high, the water vapor that emits the outgoing radiation is at relatively high levels in the atmosphere; near the poles, where the temperature is low, the emitting water vapor is at lower levels. But the intensity of the outgoing radiation, which depends on the temperature of the water vapor, and not on its elevation, is nearly the same in all latitudes. On the other hand, the solar radiation absorbed decreases with latitude and, as a result, local radiative equilibrium is not approached.

On a planet where water vapor is the principal radiating medium, the initial radiation imbalance must persist and (if the planet rotates rapidly enough, and its vertical thickness is small enough) the poleward temperature gradient must necessarily grow to the point where the flow becomes baroclinically unstable. On such a planet the form of the general circulation must become that of the planetary wave regime—such as we observe in the Earth's atmosphere.

On the other hand, in an atmosphere in which the concentration of the principal emitting gas is not dependent on temperature, the outgoing radiation will decrease with latitude as the temperature decreases with latitude. This atmosphere could acquire an equilibrium poleward temperature gradient smaller than the critical limit for baroclinic instability. In such an atmosphere, regardless of the rotation rate, the persisting form of the general circulation

would be that of the symmetrical meridional circulation and symmetrical zonal vortex.

If Venus, for example, has only carbon dioxide as its principal emitting gas, the general circulation of the Venus atmosphere should have the simple symmetrical form, with no cyclone-scale waves or disturbances such as we observe on Earth.

This analysis of the dynamics of planetary circulations, which I have presented in a qualitative way, can be carried out quantitatively. Studies of this kind are being made by several investigators, including my own group at UCLA. We are numerically integrating the equations of atmospheric motion, with the heating and friction terms retained. The integrations must be carried out in short time steps to avoid computational instability, and over long periods of time because the large scale atmospheric motions develope slowly. Consequently large amounts of high-speed computer time are required. Something of the order of 100 hours of IBM-709 time, or the equivalent, is required for even a relatively simple numerical planetary circulation experiment, and hardly any of us working in this field are able to get the computer time we need.

Now I would like to comment on another matter in which I know many of you are interested, that is, the question of the composition of the clouds that are visible on Venus, and the temperature of the surface of the planet beneath the clouds.

I would like to point out that it is not reasonable to assume that the clouds of Venus are water clouds and at the same time believe that the temperature at the base of the clouds is as high as 600°K, which is the usual interpretation of the centimeter radiation measurements. I make this statement because in an atmospheric layer that is wholly or partly filled with water clouds, the dynamically limiting vertical temperature gradient is approximately the adiabatic rate for saturated air, and this rate falls off rapidly with increasing temperature. To reach a temperature of 600°K, following the saturated adiabatic temperature curve downward from a cloud top temperature of 250°K, the cloud layer would have to be hundreds of kilometers thick. Such a cloud layer would not permit the downward penetration of the sunlight necessary to maintain the high surface temperature and the convection necessary to maintain the clouds. A greenhouse will not work, after all, if it is made of dirty glass.

DR. UREY: Are you assuming that liquid water exists on the surface?

DR. MINTZ: Perhaps you are thinking of a thin layer of water clouds in the air?

DR. UREY: That is right. It has been suggested that perhaps there is a thin layer of clouds that range but never get to the surface. Do you agree with this as a possible explanation?

DR. MINTZ: A thin layer of clouds floating high in the Venus atmosphere raises other difficulties. One of these is that it is hard to understand why a layer of water cloud that is high in the atmosphere, and presumably formed by condensation in adiabatically expanding rising air, should form a continuous shell around the whole planet. It has been suggested that the air may be descending and the cloud dissipated on the dark side of the planet. But with no cloud on the dark side, one would expect that the 8 to 13 micron infrared radiation would come from a lower level, and hence from a much warmer level, on the dark side than on the cloud-covered day side. However, the 8 to 13 micron radiation measurements do not show this.

A suggestion for a direct instrumental study of the circulation of the Venus atmosphere—rather than continuing to rely only on indirect observations or dynamical theory—would be the use of constant pressure or constant density balloons whose drift would be monitored from a parent satellite that remained outside the planet. But that, I suppose, is in the very far distant future.

CHAIRMAN BERKNER: The capabilities for doing this are not in the distant future, in the sense that we can delay planning for some of these experiments, so I hope it will be discussed further.

As I have to leave, I will ask Dr. Kellogg to take the Chair. I suggest that you finish this discussion of dynamics. You might examine the methods or approaches for studying these phenomena. Also I suggest some discussion of ionization and its effects on magnetic fields. Dr. Eshleman will also have some comments which relate to the measurements of cloud levels and rotation.

DR. MINTZ: May I try, again, to comment on Dr. Urey's question?

DR. KELLOGG: We have several things yet

to cover, and I think the fact that the question has been opened is perhaps the important thing. We have been discussing the question of the meteorology of Venus. We have not considered the meteorology of Mars, and I think we probably are doing Mars an injustice to ignore it; but in order to proceed I would like to pin down the meteorologists and the atmospheric scientists a little further on what they think are the important measurements to be made on a planetary atmosphere.

Dr. Jastrow has suggested that we shall have to make the kind of measurements at the surface that we are accustomed to make for the Earth. Others have expressed the feeling that we can learn much by other planetary observations or balloon observations or by fly-bys, without actually having to penetrate the atmospheres. Would it not be desirable to consider this question a bit more? What would we do if we could send a probe into an atmosphere and land it on the surface? Would anybody like to summarize the most important first observations to make with a penetrating probe?

DR. MINTZ: The surface pressure would be the single most important piece of information we could get. That would be the last pressure reported from a hard landing. And if, on the way down, we could measure temperature as a function of pressure we could get the temperature-height curve—approximately, if we don't know the actual composition of the gas—by integrating the hydrostatic equation. Atmospheric composition would be the next thing to study.

UNDENTIFIED SPEAKER: I don't know how you would determine composition from a probe penetrating the atmosphere, but I suggest that this is one thing that can be done by ultraviolet studies from an observatory orbiting about the Earth. We assume a lot of nitrogen on Mars; we assume that there isn't much nitrogen on Venus. If we had an observing platform, where we could observe the ultraviolet, we could say something definite about these things instead of making assumptions. This is something we could do about the atmosphere of planets from a satellite orbiting the Earth.

I have another suggestion. It has been shown that scintillation in the Earth's atmosphere tells you something about direction and speed of winds at the upper tropospheric levels. This might be an excellent way of studying planetary winds, although you would have to put an anemometer on board.

DR. KELLOGG: Dr. Hess has suggested that one could actually get atmospheric compositions by ultraviolet measurements, without ever entering the planetary atmosphere. Is there a possibility of making quantitative estimates of the atmospheric composition from a balloon or Earth satellite by using ultraviolet methods?

DR. DE VAUCOULEURS: No, not from the Earth. From a probe you might.

DR. KELLOGG: You are saying that this would require getting closer to the planet with a probe?

DR. CHAMBERLAIN: To voice a dissenting opinion, if you could look extremely far in to the ultraviolet, I think that you would get the absolute abundance of nitrogen just by measuring the absorption spectrum, the same as we do for any other molecule. The Lyman-Birge-Hopfield bands are weakly forbidden. If there is more nitrogen than that, one could look at a very strongly forbidden band system. Of course, in the case of Venus, we would not learn how much nitrogen exists at the surface, but at least we could determine how much nitrogen is at the cloud layer. These measurements would be extremely helpful in resolving many of the controversies existing today. All of this work could be done from just outside the Earth's atmosphere.

DR. EDSON: It occurs to me that we greatly need ultraviolet observations from the Earth to determine more precisely what to look for with a probe. These studies will help to determine the nature of the probe experiment or the dynamic range in which it is to be set. This is a fine example of how one needs to integrate all methods in support of one another. Here we probably can learn about the constituents of the upper atmosphere by using ultraviolet techniques that give us exactly the clues we need to make simpler and better instrument designs for probing a planetary atmosphere. The techniques of molecular contact, where the molecules of the apparatus are in contact with the molecules of the target, can then be applied. This is the unique ability of a probe.

DR. HINTEREGGER: I think we should distinguish between the two problems of using ultraviolet and extreme ultraviolet techniques in emission and in absorption. These are quite

different techniques; absorptions will probably require a fly-by, whereas emission studies could be conducted from an orbiting Earth satellite observatory.

In the fly-by, the amount of information gathered by observing the absorption from the Sun would require that we gaze through the upper atmosphere of the planet. Even if there is nothing much to be looked at in the extreme ultraviolet for the lower atmosphere of any planet, the upper atmosphere is bound to be extremely interesting with this technique. Because of dissociation, the upper-most planetary atmospheres will probably consist mainly of atomic constituents; consequently, a study in the extreme ultraviolet, not necessarily by probing into the near region, is something within range, perhaps, of intermediate projects. A vertical probe scanning above the ground level of a planet might be instrumentally much more difficult than a shot in which you have a chance to look at the Sun with at least a part of the outer atmosphere of the planet in the optical path. If we learn more about the outer atmosphere of the planet, we will probably gain some nice clues as to the inner atmosphere, because the latter is strongly dependent on all the photochemical reactions taking place at the various levels.

DR. KELLOGG: This brings up an important point. Do we really want to know about the upper atmosphere before we know about the lower atmosphere of these planets?

DR. FRIEDMAN: You can probably do both in the same try if you have a hard landing and are using spectrographic methods. You can very easily design your instrument to measure all the way down to the surface.

DR. HINTEREGGER: And I might add that some of the problems—not those of making mass spectrometric composition measurements—are nonexistent if the Sun is used as a light source for an absorption analysis. In other words, if we observe the absorption of solar radiation, our sample is the undisturbed atmosphere away from the vehicle. I think this is a great advantage over the application of mass spectroscopic devices and density gauges which are somewhat limited by distortions.

DR. KELLOGG: If we are going to use mass spectrographs for air analysis at all, we may draw another conclusion: we would be more interested in mass spectroscopic observations at lower levels, perhaps on the surface, than in those of the upper atmosphere, because of the problem of sampling. Is that a reasonable statement?

DR. NIER: The problem of sampling becomes serious only when you want quantitative answers; if you want only orders of magnitude, I don't think that problem enters. The degree of accuracy will be the determining factor, and here you may well need mass spectrometers.

MR. DUBIN: The mass spectrographer requires a vacuum. If you get to the ground you can use a field to excite the gas and look at it with spectrometers. This is within the realm of possibility.

DR. FRIEDMAN: It is also possible to carry a light source with the same type of detectors that you would use in the outer atmosphere with the Sun as a source; when you can no longer see the Sun, you carry your own ultraviolet source.

DR. SEYMOUR HESS: I am very much interested in the nature of the blue haze of Mars. If we are going to drop a probe into Mars, information that would contribute to the solution of this problem is greatly needed.

DR. KELLOGG: Yes. One way of approaching this problem is to ask: how would we measure the noctilucent cloud distribution in our own atmosphere, supposing this is a phenomenon similar to the blue haze? Can the same approach be applied to the blue haze of Mars? Venus has been emphasized in the discussion so far, and the overwhelming enigma seems to be involved with what is under that cloud deck. On Mars the problem is a little bit different, because we can see down to the surface.

What should we put first on Mars to investigate parameters other than those of temperature and pressure at the surface—a question Dr. Mintz has also raised?

DR. HARRY HESS: What about photographs?

DR. KELLOGG: What would this give you with regard to the atmosphere?

DR. HARRY HESS: In the past oceans may have existed on Mars. There should be erosional features, corresponding to erosion on the Earth, that could be picked up photographically.

DR. KELLOGG: If you are unlimited in the amount of information you can send back, photographs make a lot of sense. However,

so far as I can see, we are going to have trouble recovering film from planetary probes in the next decade. We would have to telemeter the information with a somewhat limited transmission capability. Therefore, the high resolution that Dr. de Vaucouleurs mentioned as being possible from a space probe would, I think, be unattainable, unless you looked at some very small area and were willing to settle for the details of that small area. This is something we have to keep in mind when we talk about experiments in space probes: how do we get the information back?

DR. EDSON: If we attempt to send a whole image back, we have the problem of transmitting a great deal of information. If we make the probe a little smarter and postulate that the surface of Mars looks this way or that way, we can classify the different ways, and enable the probe to decide which of these sets of characteristics is more nearly like what it actually sees. Then a choice among a few dozen photographs would put the face of Mars together. If we make the probe smart enough we can make it decide for us.

This is a problem of systems, and by organizing it, and having a pattern of thought within which to think about it, we will make better progress. In fact, out of this discussion and others like it, is coming a discourse which amounts to a systems concept.

DR. KELLOGG: I would like to change the subject at this point. Dr. Eshleman mentioned radar and radio observations that could be make from the Earth, and I have heard something about the use of radar from space probes also. He indicated that it would be possible to measure the size of the solid surface of Venus by use of ground-based radar. I have also heard it said that one could measure the rotation rate from a space probe by using Doppler measurements. I wonder if one could also get a radar reflection from the top of the clouds of Venus?

DR. ESHLEMAN: We can get some idea of what can be done with ground-based radar from the diagram, Figure 1, which is a plot of the logarithm of echo strength versus the logarithm of the echo delay time, or essentially the logarithm of the distance to the planet involved. Venus, at the closest approach, has a certain radar echo strength and a certain echo delay time, and as it goes around its orbit it would then have greater delay times and less echo strength. In the diagram we see that the echo delay time for Venus varies from about 5 minutes at inferior conjunction to about 30 minutes at superior conjunction, while the echo power varies from about 70 to 100 decibels below an echo from the Moon (i.e., the echo power varies from 10^{-7} to 10^{-10} of the power of a Moon echo). The other planets out to Saturn are also plotted here to show their expected echo strengths. In each case it is assumed that the planet is similar to the Moon in the way that it scatters radio energy. The Sun requires decimeter wave lengths for radar detection, inasmuch as meter and centimeter waves would be absorbed highly in the solar corona. At a wave length of 10 to 15 meters a Sun echo would be a hundred times stronger than an echo from Venus.

As you know, the Lincoln Laboratory radar at Millstone Hill, operating at 400 megacycles, can just barely detect Venus with some minutes of integration. The Jodrell Bank antenna has also been used to obtain weak echoes from Venus. The Cornell Radio Observatory that is being installed in Arecibo, Puerto Rico, should have about 40db (10,000 times) greater radar sensitivity. So, with the same kind of resolution we are already talking about the possibility of observing Venus all the way around its orbit, and Mercury and Mars over most of their orbits, and probably observing Jupiter as well. Other short-wave length radars of comparable or even greater sensitivity are being built or proposed by the Lincoln Laboratory, the Naval Research Laboratory (using the 600-foot parabolic antenna), and the Stanford Research Institute. This describes just one set of possible measurements, all in the meter and centimeter wave lengths, where the reflection is presumably from the surface of the planets.

Another class of measurements, which is more germane to the subject of the atmospheres, is the use of longer wavelengths so that planetary ionospheres may be detected. Also, long wavelengths are needed to study the Sun and the interplanetary medium, and other 'soft' targets. The Sun was detected with a long wavelength system, again with some minutes of integration. Stanford University is currently building another long wavelength (5 to 15 meter) system which is about 10 times more powerful than the first

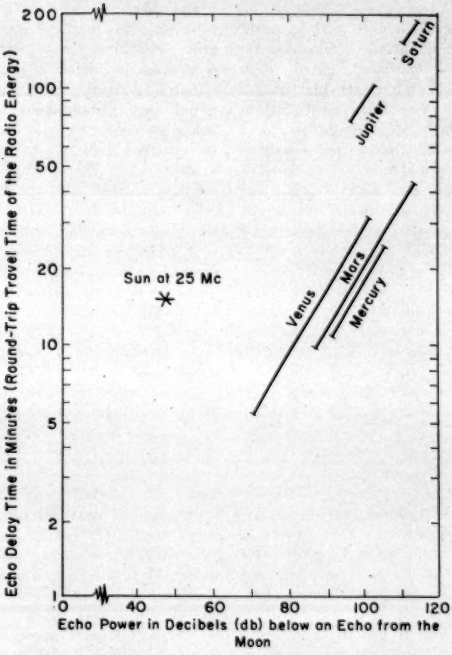

FIG. 1—Radar echo strength versus planetary distances.

solar radar, and which could be used every day for solar studies. The Lincoln Laboratory will soon have in operation in Texas an 8-meter radar which is almost 30db more powerful than the first solar radar. For the more distant future, the Stanford Research Institute and Stanford University have proposed the construction of a steerable 800-foot parabolic antenna and a 10-million watt transmitter for more sensitive measurements at wavelengths longer than about 3 meters.

We have seen that radar detection may soon be possible throughout much of the solar system by using both short and long radio wave lengths. However, I want to stress that radar is good for much more than mere detection. With more powerful radar systems it will be possible not only to detect more distant objects, but also to study the nearer objects in detail by using the very high signal-to-noise ratios that will be available.

DR. KELLOGG: What will this tell you?

DR. ESHLEMAN: I would like to speak in terms of resolution on a planet. Perhaps you have seen the publication of the Lincoln Laboratory concerning radar resolution on the Moon, using a range-Doppler display. If we look at a single range interval or one time interval in the echo, we are measuring the reflections from a particular range circle on the face of the target. If, in addition, the target is rotated somewhat there will be a Doppler spread, and a region of constant Doppler shift will correspond to a small circle perpendicular to the range circles. Thus,

if we look at one range interval and one Doppler wave length interval, we are resolving two small regions on the planet (at the intersection of the orthogonal circles) that have a unique range and a unique Doppler shift.

Perhaps the most interesting feature of range-Doppler resolution is its independence of distance to the target. Given unlimited radar power, resolution on the order of meters could conceivably be obtained on all the planets. Thus, obtaining such radar resolution is limited only by technology or cost.

DR. KELLOGG: Do you think that the existing systems will give the rotation of Venus?

DR. ESHLEMAN: Yes, I believe so.

MR. DUBIN: With what accuracy?

DR. ESHLEMAN: The accuracy would improve with better radar sensitivity and length of observation. As with most initial experiments, the first results would probably give a relatively low degree of accuracy, but this would improve very greatly with the more sensitive radars that will soon be in operation.

DR. KELLOGG: With two frequencies—one of which is low—would it be possible to determine the height of the ionosphere?

DR. ESHLEMAN: Yes, I believe this would be possible. Let me stress again my main point that we will soon be able to obtain high echo strengths. Once we have strong echoes, many different measurements can be made. Very careful comparisons can be made between the echo characteristics and the characteristics of the transmitted waves, and the precision of the comparison would increase with the echo strength.

The use of two frequencies as suggested here is just one possible means; with these frequencies we can hope to measure the ionospheric heights, and perhaps also the height of the clouds. I don't know how much discontinuity to various wave lengths the clouds cause. If you can find a frequency where the long wavelengths will get through the dust and the ionosphere, and a shorter wavelength that would be reflected from the dust, you can then measure the height. The other obvious measurements to make with two frequencies are the integrated ion density in the planetary ionospheres, and the interplanetary densities between the Earth and the planets. With the long and short wavelength systems that Lincoln Laboratory will soon have ready for use, it may be possible to measure the slight difference in propagation time of two wavelengths on Venus echoes, and get an average measure of the interplanetary gas densities between the Earth and Venus. At Stanford we are already trying this technique between the Earth and the Moon, and we hope to have some answers before too long.

DR. KELLOGG: Is this an experiment which might be feasible in the next year or two?

DR. ESHLEMAN: Yes; on the next close passage of Venus it might be possible to measure the interplanetary gas density. I would say that the rotation rate on Venus and the interplanetary gas density would be measured within the next couple of years, but it is only with much larger radars that we can measure cloud cover heights and ionization densities near the planet itself.

DR. UREY: For this would you need radars more sensitive than the most sensitive now being planned?

DR. ESHLEMAN: With the most sensitive systems now being planned, such atmospheric and ionospheric measurements might be feasible.

DR. UREY: What are the wavelengths up there (referring to a diagram, on the black board, for the proposed radars)?

DR. ESHLEMAN: These wave lengths vary from a few centimeters to one meter for the short wavelength radars, and up to 12 meters for the long wavelength radars.

DR. UREY: Could you determine the thickness of the atmosphere below the visible clouds for example, whether or not it is thirty kilometers thick?

DR. ESHLEMAN: If the characteristics are such that with 30db signal-to-noise ratio on the planetary echo you can get a special effect at the top of the cloud cover, that would be possible.

MR. DUBIN: If the size of the dust particles is only three or four microns, they may be too small for wavelengths of a few centimeters.

DR. UREY: Well, they are micron-sized particles, or at least you can't assume something much bigger. So you cannot determine the depth of the atmosphere in this way.

DR. ESHLEMAN: It is quite true that micron-sized particles would have very little effect on waves at centimeter wavelengths. However, there might be other effects, such as a sharp discontinuity in dielectric constant due to constituents other than the solid particles.

Certainly terrestrial clouds give fairly good radar echoes at short wavelengths. Also, if the particles are charged by photo emission, they might be surrounded by a space charge that would make the top of the cloud cover a rather good scatterer at relatively long wavelengths. With very high echo strengths from the surface, rather small effects in the atmosphere could be detected.

UNIDENTIFIED SPEAKER: You are speaking of the height of the visible cloud deck. But you already know the pressure of the atmosphere above the cloud layer, and you should be able to put together an ionosphere based upon the radiation. You could measure the top of the ionosphere, and hence the depth of the atmosphere also.

DR. ESHLEMAN: Another possibility comes to mind for measuring the height of the cloud cover on Venus. If we could tell you the dimension of the solid surface, could you tell us the visible angular size accurately enough to determine a useful height of the cloud cover?

DR. DE VAUCOULEURS: Yes, we could. The shell, in the upper atmosphere, that caused the density drop in the fading phase—we know its radius—is always expressed in terms of the apparent radius at unit distance (i.e., one astronomical unit). This is 8.51 seconds of arc, and is the radius of a certain sphere where we know the pressure is 2.6 dynes per square centimeter. We know, also, the apparent radius of Venus. The optical apparent radius of Venus, as defined by the top of the cloud layer is 8.41 seconds, or one one-hundreth of a second of arc, so we are already limited by the accuracy of the data.

DR. ESHLEMAN: If Venus has a surface anything like the Moon, and we talk about improvements of 40db, or ten thousand times more than mere detection, you should get echoes from the limb. With the range-Doppler type map we should get the diameter to very good accuracy—a few kilometers or less.

DR. UREY: The diameter is 10,000 kilometers, so one part in two thousand is 5 kilometers.

DR. ESHLEMAN: I believe we can get a similar type of accuracy on the radius of the solid surface.

DR. MINTZ: Would photographs from a balloon-borne telescope give us an accurate diameter of the visible surface?

DR. DE VAUCOULEURS: Yes, from the surface of the Earth we have determined the optical diameter of Venus to a few one-hundredths of a second of arc; this is not quite a fair statement, as I selected a certain group of photographs where we believe this is possible. However, if it is true, by careful photometry of the edge from a balloon we should be able to measure a few thousandths of a second of arc.

DR. EDSON: The balloon should afford an improved opportunity to make measurements comparable to the precise optical measurement of the diameter, which I did years ago. At inferior conjunction the crescent is very thin compared with the optical resolution, and you don't have to worry about irradiation or other edge effects. You can lay the fiducial line very precisely on the image and get an excellent diameter, which is in effect the diameter of the top of the cloud deck at the time of the observation. If a balloon observation were made at the same time as the radar observation, and if there is a change in the cloud deck of more than two kilometers—which would not surprise me—this would be detected.

DR. HADDOCK: The radar echo measurements will give us an indication of the reflectivity of Venus. If the reflectivity of Venus is a half, say, of its black body temperature of 580° K deduced from radio emission measurements, this would indicate that you have to double the physical temperature of the rocks of Venus to account for the radio emission, if it is indeed of thermal origin. Now, if you take granite and sandstone, and compute what you think the emissivity would be at centimeter wavelengths, you come up with about 25 per cent reflectivity. This would be 75 per cent emissivity, or an increase from the 580° K to about 770°K. Another point: by measuring the emission from Venus with very good precision over a period of several months, it might be possible to get the period of rotation of Venus from variations in the radio emission, if the emissivity of the planet is irregular.

I might also say, if you measure the emissivity of Venus at other frequencies—I have in mind one and a quarter and one and a third centimeters (ammonia absorption lines)—you might get evidence on the water vapor content. This is a measurement that is certainly within the capability of a few installations in the country. It is just a matter of getting someone to really push on it.

UNIDENTIFIED SPEAKER: How were the radiometric measurements reduced?

DR. HADDOCK: The radio astronomers merely say that the radio emission from Venus is equivalent to 580° K. The only evidence that the emission may be thermal derives from the fact that, from 3 centimeters to about 20 centimeters, the deduced black body equivalent temperature is approximately constant. It is difficult to think of a mechanism that would give a constant black body temperature by invoking such things as synchrotron radiation. If you do drop a probe into the atmosphere of Venus, I suggest that you have radio receivers that can record emissions from the Venusian ionosphere that cannot escape, such as lightning discharges.

DR. KELLOGG: Dr. Chamberlain, can we turn to the next item on the agenda, the discussion of ionization and the magnetic fields of the planets? We have already touched on ionization.

DR. CHAMBERLAIN: Principally, I would like to comment on theoretical considerations that may be used to deduce the characteristics of a planetary ionosphere. First, let us look at the conclusions that can be reached tentatively, without any actual measurements. They will be of extremely doubtful value because a planetary ionosphere is so critically related to its composition.

We might make a guess as to the rate of ion production in a planetary ionosphere in the region corresponding to the Earth's *F* layer, by assuming a principal ionizable constituent. The main ionizable constituent is likely to be atomic oxygen in the inner planets, and perhaps atomic hydrogen in the outer planets. Knowing only what is ionized, however, does not tell us what is the level of ionization, which depends also on the rate of recombination. Herein lie the extreme uncertainties.

We could guess at the amount of ionization by supposing that the recombination process is radiative recombination. For example, O^+ recombining with an electron is extremely inefficient, and it is hard to believe that any ionosphere would really operate so inefficiently. If there are molecules present, the recombination process would be slightly more complicated, but the ions would disappear more rapidly.

Thus we would first like to know what constituent is being ionized, and second, the constituent that is recombining. They don't have to be the same. For example, in the *F* region of our own atmosphere, atomic oxygen is ionized by sunlight, but recombination is most likely to occur through NO^+, because there is a transfer of charge by an ionic-exchange reaction that occurs between ionization and recombination.

Further, the amount of ionization is related to the temperature: to know the rate at which recombination occurs we have to know the temperature. It is a sensitive problem because the temperature of an ionosphere is, in turn, governed by the amount of ionization. This brings us to the problem that Dr. Urey raised this morning; we shall have to examine the ionospheric heat balance to see what governs the temperature of the highest part of the atmosphere.

Heat is injected into an ionosphere through photoionization. In the Earth's *F* region the ionized constituent is atomic oxygen. This has posed a problem for years, because the temperature that was believed to exist in the upper atmosphere, 1500° or 2000° K, could not be explained only by the amount of heat absorbed in ionizing atomic oxygen. Various ways have been proposed, from time to time, to get around this. It is now beginning to appear that the probable explanation is that N_2 is also ionized. But N_2^+ recombines so fast that it is not apparent in the daily variations of the ionosphere, and so has remained effectively hidden from ionospheric experimentalists. Thus we have an enormous heat source that ordinarily is not detectable from the ground, except perhaps under eclipse conditions; yet it supplies a great amount of heat to the upper atmosphere.

The temperature is governed, of course, not only by how much heat is put in, but also by the mechanism through which the heat is removed. In our own atmosphere it is removed principally through conduction. A steep temperature gradient in the *F* region causes a heat flow downhill toward the *E* region. It takes an enormous amount of heat input to supply the heat that must be flowing down that temperature gradient. This was, I think, first emphasized by Spitzer.

The second way of removing heat from the upper atmosphere is through radiation. The main process in our own atmosphere involves a forbidden oxygen line which arises from what

astronomers call a 'coronal transition,' between two levels of the ground term of the oxygen atom. The emission lies at about 62 microns, but it is excited by ordinary thermal collisions. It seems that, second to conduction, this radiation is causing the greatest cooling of the *F* region.

The main conditions for our own ionosphere are conduction, and the 62-micron line. Suppose, however, that the molecules in the planetary ionosphere are not homonuclear. In our own ionosphere we have principally N_2 and a bit of O_2. If CO were present, it would be a very strong factor in cooling the ionosphere, because thermal collisions could then excite the vibrational levels, and radiative transitions downward would emit energy immediately and cool the ionosphere.

In the Earth, the homonuclear molecules will not give these transitions, so they are not effective as thermostats, and the abundance of minor constituents present—OH, CH, et al—turns out to be much too small to be effective in cooling the ionosphere. All of these things are critical, and I think it would be very difficult in any particular example to identify with much confidence the ionization level, the ionization process, or the recombination process, without direct measurements on a planetary atmosphere.

In answer to Dr. Urey's question this morning, I see no reason why the ionosphere of Mars, for example, could not be quite cool; I don't see that it is necessarily several thousand degrees. Incidentally, the Lyman-alpha experiment I mentioned this morning would furnish a means of measuring the exospheric temperature, through the scale height of hydrogen in the outer atmosphere.

First, as to observational techniques for investigating planetary ionospheres radio soundings are still the most obvious means for studying maximum ionization densities and, of course, the decrease of ionization below that peak.

Second, radio studies should be made of the gyroradiation, that is, the radiation from electrons accelerated in the magnetic field. These studies would give direct information about the strength of the magnetic field. Of course, if we can actually get to the planet, the best way to measure the magnetic field is to take along a magnetometer. In the absence of that, the gyro-radiation is informative; it has already given an indication of the strength of the magnetic field on Jupiter.

A third type of experimental measurement concerns the night airglow, which could provide direct observation of the recombination process. By analogy with the Earth's ionosphere, the recombination occurring from NO^+ dissociates the N and the O, and leaves the O in an excited state, which we detect through a red emission line of the night sky. If there is a similar recombination process, say on Mars, then we should see a strong red line; or if it is pure nitrogen, we should see a corresponding forbidden nitrogen line in the night airglow. This would vary, of course, as one goes from the evening twilight zone to the morning zone, because the intensity decays after sunset.

A fourth type of measurement is associated with the twilight airglow, by which we can get direct measurements of the density of such ions as N_2^+ or O_2^+, etc. We have been talking today about the use of mass spectrometers; if one could drop a functioning mass spectrograph through the high atmosphere, there is less point in doing the twilight spectroscopic work. However, we do not have to get nearly so close to make optical observations.

Another point I want to mention about optical work relates to the question, 'Do we need to send a spectrograph to the neighborhood of the planets just to obtain increased resolution?' I feel we should not send the spectrograph there only to get an increase of spatial resolution over that which could be obtained from an Earth satellite pointed at the planet. We should also take advantage of the trip to get a different aspect, a completely different view of the planet, than we can get from the Earth. Thus, we should emphasize studies of the night side of Mars, or the twilight zone on either Mars or Venus. In this way we can initiate a completely new mode of planetary study.

DR. UREY: I think Goody showed, years ago, that carbon dioxide above the level of the Earth would be a very inefficient radiator because the collisions would be too few to feed energy into the carbon dioxide molecule in such a way that it could become an efficient radiator. Would the same thing be true about carbon dioxide in the high atmosphere of Mars?

DR. CHAMBERLAIN: As I remember this type of work—and I am actually thinking of work

by Bates—carbon dioxide is extremely inefficient for radiating in the upper atmosphere only because it is an extremely minor constituent.

DR. UREY: Maybe I don't remember it correctly, but I thought it was because the accommodation coefficient for the transfer of translational energy to the vibrational degrees of freedom is very inefficient. Rotation is very efficient, but vibration is inefficient.

DR. CHAMBERLAIN: You are right. It is a combination of the abundance and the frequency with which vibrational collisions occur.

DR. HINTEREGGER: I would like to raise a more general question. We have made some recent measurements of solar photon fluxes in the regions that are responsible for the ionosphere at higher altitudes, and I have some preliminary data on the calculated probability per second of atomic hydrogen, atomic nitrogen, atomic oxygen, and helium. They are generally of the order of a hundred to two thousand, 10^{-3}/sec. The corresponding time required for a neutral particle to become ionized due to solar radiation ranges from some ten days to, perhaps, several months.

I would like to direct a question to those concerned with the solar winds. Is it believed that the ionization due to charge exchange with fast protons from the solar wind would be considerably higher than that due to extreme ultraviolet absorption? Or is this a question that should be postponed? In a recent consideration of the lunar atmosphere, by Licht and Herring, the solar wind is supposed to lead to the existence of a lunar hydrogen ionosphere; I think it is implied that the dominant ionizing agent is not solar radiation but is the charge transfer from the fast solar wind protons to the slow hydrogen atoms. These cool hydrogen atoms of the Moon are supposed to emerge from the neutralization of the fast protons at the lunar surface.

As applied to all planets we have at least some preliminary experimental picture of the expected probabilities of ionization due to the solar spectrum (soft X ray and extreme ultraviolet). I would like a clearer understanding of the competitive effect due to the solar wind proton ionization, because then one could establish some better limits of the highest possible particle density that could exist in neutral form in any planetary atmosphere, if one makes any assumptions about the constituents.

DR. KELLOGG: This obviously depends on whether the solar wind penetrates down into the atmosphere.

Dr. Chamberlain, have you anything you would like to say about magnetic fields of planets?

DR. CHAMBERLAIN: I have two remarks. First, if an instrumental package can get close to a planet it should measure the field directly with a magnetometer. The Van Allen radiation would be an indicator of a field and perhaps even of the field strength, and it is of interest in its own right. If we are close enough to measure particles directly, however, we can also measure the field directly with a magnetometer and this is certainly preferable.

My second point is that gyroradiation studies are a possibility for remote detection of magnetic fields; I have already discussed this possibility.

MR. DUBIN: How about the polar aurora?

DR. CHAMBERLAIN: If we could see a clear-cut auroral zone, it would be good evidence that the planet has a magnetic field, but, unless someone has an auroral theory, I don't know that it would tell us much about the strength of the magnetic field.

DR. HINTEREGGER: I would like to go back to this solar proton wind. Is it possible to use its measurement to investigate the magnetic fields of planets? If solar wind protons are as intense as they were believed to be (of the order of 10^{10}–10^{11} per centimeter per second), or even if the fluxes are much smaller, measurements of the distortion of the solar wind near shading areas of the planets could be made with existing techniques for measuring charged particles. With probes that don't have to be necessarily very close to the planets, we might get some preliminary information on magnetic fields of the planets by measuring the distortion in the solar wind proton field.

Professor Rossi and his group at Massachusetts Institute of Technology are preparing equipment for measuring solar wind protons by use of retarding potential analysis in parallel plane geometry with a square sweep in the kilovolt range. I am not qualified to discuss it, but this and other methods are available for direct instrumental studies of a solar wind proton field in interplanetary space.

DR. ESHLEMAN: California Institute of Technology has already measured radiation around Jupiter, although I don't know the details. Dr. Chamberlain, did you not discuss this?

DR. CHAMBERLAIN: That work was the example I cited to indicate that gyroradiation measurements from some distance away could be used to get an idea of the magnetic field.

DR. ESHLEMAN: There is some possibility of being able to measure ionization density in the atmosphere of the planets from two different or the twilight zone on either Mars or Venus. radar measurements. One would be a measure of gas density weighted by the magnetic field but including the interplanetary gas; the other would be a measurement independent of the magnetic field, but including the interplanetary gas. Between the two of these you could get the integrated density through the ionosphere.

DR. DE VAUCOULEURS: I would like to remind you that we do have weak evidence of the magnetic field around Venus in addition to doubtful observations of the aurora.

EVENING SESSION

CHAIRMAN BERKNER: I have asked Dr. Urey to summarize today's discussion.

DR. UREY: The problem of planetary atmospheres is just as complicated this evening as it was this morning, and it is just as difficult to give a review of what we have done today as it was to try to give a summary of what would be done at the beginning.

We have had a review of the photochemistry of the high atmospheres of the Earth, where we find very considerable amounts of molecular dissociation and ionization but very little atomic nitrogen. Mostly it is in the molecular form, we believe. Ozone exists, as we know. The many constituents are tied together by an exceedingly complicated set of chemical reactions. An enormous amount of empirical study is necessary in order to understand these phenomena at all. This has been true for many years, and I think it will probably be necessary to get much more empirical data in regard to these problems before we will understand them well.

When we go to the other planets, we have the problem of constituents different from those in our own atmosphere, principally the lack of oxygen in these atmospheres. It is necessary, then, to consider what the other possible constituents will do, and it becomes an exceedingly complicated problem. Dr. Chamberlain also went on to discuss ionization and the effects of magnetic fields; his conclusion in this case was that, without a great deal of empirical data, it is practically impossible to predict what will be observed in a planetary atmosphere.

Professor de Vaucouleurs and Dr. Sinton discussed the constituents of planetary atmospheres; much of this material is, of necessity, quite old to those of us who have been reading the literature of planetary atmospheres. Very little has been added to our understanding of the composition of these atmospheres, and really very little in regard to temperatures. Perhaps the most interesting new result of our discussion was an expression of rather firm conviction by Dr. Sinton that the high temperature of Venus reported from radio studies is real, 300 degrees centigrade or thereabouts.

This gives considerable difficulty because of the very great depth of the atmosphere that is predicted on this basis. Especially this is true if the atmosphere is wet; the depths must be so great, in fact, that Sinton and de Vaucouleurs think that the clouds of Venus, if they are, indeed, water (as indicated by Strong's experiments) must be only a thin layer of clouds in which raining and re-evaporation occur.

Another interesting and new feature is the work of Dr. de Vaucouleurs, who has studied the occultation of Regulus. He did a magnificent job in reducing these data, and has been able to get a scale height and pressures for the high atmosphere of this planet.

The possible presence of N_2O_4 was suggested on the basis of Kiess' observations. The conclusion from our discussion raises doubt that large amounts of N_2O_4 are present in the atmosphere of Venus, or in the atmosphere of any other planet. There are very serious difficulties in accepting this as a proper explanation, because of the great instability of nitrogen oxides.

Dr. Mintz gave us a discussion of the circulation of atmospheres, and in listening to this I realized again how very little I understand this complicated problem. If I understood Dr. Mintz' discussion correctly, he is somewhat skeptical of a high temperature at the surface of Venus, and, I think, finds it very difficult to understand how such a high temperature can exist. This comes from the difficulty of under-

standing how there could be an effective greenhouse effect. It would be necessary to have light transmitted to the surface of the planet; this seems to require clear skies, at least over part of the planet, which, apparently is not the case. It is very difficult, therefore, to understand this greenhouse effect, and there seems to be no other explanation for the high temperature below the surface of the clouds. However, thirty or forty per cent of the visible light falling on Venus is absorbed and is available for producing a high temperature if it cannot be radiated as infrared radiation.

No mention was made today of other possible constituents than water for the cloud cover of Venus. Other suggestions have appeared in earlier literature. I do not know whether to take it that our speakers today have concluded definitely that the other possibilities are impossible. Silica dust and carbon suboxide have been suggested. I believe the carbon suboxide idea was first put forward by Dr. Sinton some years ago.

The situation with regard to these problems has not changed at all in a year and a half. Most of the things that were discussed today, with the exception of the few new points that I have mentioned, were discussed in the first meeting of Committee 1 of the Space Science Board, and there has been little change in this subject since. From time to time we explain this situation to a new group of listeners, but this does not lead to effective progress.

A discussion developed, especially by Dr. de Vaucouleurs, partly by others, about the importance of backup programs. This is something to which I subscribe fully. I believe that we should make as much use as possible of terrestrial observatories, and support the work to be done with high-flying balloons that will back up the work of orbiting telescopes and of probes to the Moon and planets.

Certainly it is wrong to spend great effort, as we are, on the space program, and at the same time not try to get the maximum amount of information from terrestrial observations which can be made at very much less expense. This point has been emphasized before, and I am quite sure that the group will subscribe to this point of view. I have urged it, myself, in the past, in connection with the study of meteorites. We should not go to such enormous efforts to get samples of the Moon, for example, if we are quite uninterested about investigating substances that arrive at our doorsteps quite free of charge.

Dr. de Vaucouleurs particularly mentioned that *planets*, among astronomers is a dirty word. I think this dates back to the early years of the century, when a very well known astronomer was sure that there were men on Mars. Suggestions were even made that there were men on the Moon at that time.

Now, this is a bit of past history, and it is a warning to all of us at the present time not to try to sell our ideas with high pressure methods. We may drive people completely from the field and get nothing done for half a century, which I think is pretty much what happened. Some of this high pressure salesmanship exists in various branches of the subject at the present time. I think all of us, perhaps, including the present speaker, engaged in this sort of thing to some extent. Perhaps it is excusable, if it gets other people to pay serious attention to what we are proposing. But to carry on stubbornly, year after year, with high pressure tactics for advancing our ideas, is not in the best tradition or interest of science.

On the other hand, there is another point of view. It is my observation that as a field of science moves along, the methods that are being employed finally become inadequate to make any further marked advance. I believe this happened in connection with planetary science in the early years of this century. Sometimes, I have watched people working on this subject and have read their reports, I have felt sorry that men of such ability have worked so hard to get data having such comparatively small value. It is not surprising that people began to investigate the galaxies instead of working on the Moon. The large telescopes, particularly in the United States, were adequate for this purpose, and they made wonderful progress in stellar and galactic astronomy during this time.

An adequate means of investigation is needed to reactivate this subject, and I expect that high-flying balloons will be very helpful in this respect. It is my full expectation that space probes and space vehicles will furnish much more adequate means of investigation. If this proves to be the case, we will find that people

will pay attention to what we are doing and will find it interesting. We should not be discouraged by the apathy of the stellar astronomers.

Nuclear physicists are not very enthusiastic either. My chemist friends think that the things they have been doing are more important than the things I have been trying to study recently. This does not impress me particularly. I can remember some of my own experiences during the last thirty years. It is true that the old-line chemist and the nuclear physicist were much interested in heavy hydrogen, but that sort of thing was rather exceptional. It is probable that very few people of this group were much impressed by the diffusion separation of isotopes, as studied by Harkins and Hertz during the '30's nor did they believe that it would be of any importance. They also said the same things about my interest in separating isotopes by chemical methods. Today the great plants that separate deuterium are run by these chemical processes, and we all realize the importance of the diffusion process for separating the uranium isotope.

My own interests tend to remain somewhat independent of what the great majority of people wish to investigate. This lack of interest by others does not impress me much, and I urge you not to be too discouraged by the lack of interest of people who follow the general trend of science. In our laboratories we are much too interested in building apparatus without knowing what we want it for. We have been accustomed to thinking that we would like to understand a certain field of nature, and then asking what we need to do. Do we need a spectrograph, or a vacuum apparatus, or one thing or another? Then we have tried to construct the piece of apparatus that will help on the problem and permit us to carry through the experiment.

Today it is different. One does not quite know what he wants the cyclotron for, but it is built anyhow. Or, he does not quite know what he wants the radar telescope for, but he builds it and hopes that when it is built, there will be something interesting to do. Or he sends a space probe out into space and then does not quite know what it was that he was going to investigate.

This is a serious fault in the present program. The fundamental difficulty is that these groups do not have enough people whose job it is to sit down and read the literature and think about it, instead of being pressed day after day to build gadgets. I am sure that others recognize these difficulties too. This is not a new point of view to NASA or to the Jet Propulsion Laboratory, or to any of the other laboratories. One of our difficulties is that it is hard to find people who will come to our laboratories and engage in this sort of work.

Well, these are some impressions that I have had of the day's meeting. I have gone on to extend my remarks with regard to certain complaints I have held since long before we came to this meeting today.

Reviews

J. H. HODGSON, (ED.), *The Mechanics of Faulting, with Special Reference to the Fault-plane Work* (A Symposium), Publications of the Dominion Observatory, Ottawa, Canada, vol. 20, No. 2, p. 251–418, 1959, $3.00.

It is widely assumed that earthquakes are generated at faultlike structures within the crust. A rapidly growing group in geophysics has set out to determine the characters and orientations of these structures, and the forces responsible for them, based on observations made during earthquakes. The present volume gives some idea of this group's success. Although in essence an intradiscipline progress report, this collection of papers also emphasizes several aspects of the fault-plane work of wide interest to tectonophysicists and structural geologists.

Eleven papers from outstanding seismologists of the United States, Canada, Japan, Holland and the Soviet Union make up this report of a Symposium held in 1957 at the Eleventh General Assembly of the IUGG at Toronto. The subject matter ranges from theory of the motion at the source of an earthquake to the geologic implications of fault-plane solutions from recent earthquakes. *Byerly and Stauder* review the equations of first motion in Primary and Secondary phases for two causal force systems. Various uses of S phases are suggested to distinguish the more likely of these two systems for a particular earthquake. *Ingram* gives a statistical method for determining boundaries between compressions and dilatations in fault-plane solutions. *Dix* computes the energy available from rupture of elastically strained solids and finds that in order to supply a sufficiently large quantity of energy for an earthquake, a preexisting sheet-like zone of weakness must have existed. *Press* describes model studies of the radiation pattern of compressional and shear waves from a source in the form of an impulsive fault. Anomalous behavior of the shear waves according to the classical theory suggests a reexamination of the validity of this theory and caution in any present application of the theory in fault-plane solutions. *Keylis-Borok* and *Honda* give extensive accounts of the Soviet and Japanese fault-plane work respectively, and discuss the relation of the structure deduced for particular earthquakes to the regional tectonics. *Ritsema* discusses the relation of fault-plane solutions of southeast Asian earthquakes to the tectonics of the area. In common with Keylis-Borok he has found a preponderance of strike-slip faults as the source of earthquakes; by and large the faults strike at a high angle to the trend of fold belts and seismic zones. Strike-slip faulting is also important, according to *Hodgson*, in two other areas within the circum-Pacific belt. *McIntyre* and *Christie* discuss the use of a geometrical analysis of fault-plane solutions, as opposed to use of first motions in S, to remove ambiguity in the orientation of the source fault. They emphasize the disparity in results of different groups using first motions in S. *Benioff* and *St. Amand* review circum-Pacific tectonics based on a structural pattern derived in part from regional mapping and in part from fault-plane solutions of earthquakes. The current status of fault-plane studies in the light of the Symposium is summarized by the Editor.

How successful are seismologists in identifying the source of an earthquake? Current practice is to assume that there are two possible sources. The more likely is selected by comparing observed with predicted behavior of S phases, etc. One test of this whole procedure would be given by comparing results of different workers who observe the same radiation from a particular earthquake. The present volume shows considerable disagreement among such groups. It was felt that the reason for the disagreement may be inadequacy of the theory of S amplitude as well as the inherent difficulty in finding first motions in S.

Where some confidence is attached to fault-plane solutions a marked preponderance of strike-slip faults has been noted. However, there is disagreement as to fault orientation. In the Pacific such faults strike approximately perpendicular to island arcs according to one group of workers, and roughly parallel to arcs and continental margins according to another. The first of these is in keeping with the common notion that island arcs are due to a maximum compression directed normal to the arc, if indeed the earthquakes are being produced by the stresses that are responsible for the arcs. The second orientation of fault is hard to account for within a simple dynamic framework. A factor recognized here is that fault planes determined from first motions may not coincide with actual faults along which the principal motion occurs; also an earthquake may be only the expression of local distortion of a very inhomogeneous medium.

This volume is recommended for seismologists who are interested in a critical appraisal of current fault-plane work, and for tectonophysicists and structural geologists who wish to know just what can be learned about structures at the sources of earthquakes. The excellent summary given by the Editor at the end of the volume provides the cohesion and focus to the work necessary to make it informative to those outside seismology. To really understand the fault-plane work, however, it will be necessary to go elsewhere in the literature. The papers are thoroughly referenced, although the volume is not indexed. It is unfortunate that no discussion of the papers is included; one feels that

the divergent nature of certain of the results presented at the Symposium must have elicited fruitful and incisive comment.

W. F. Brace

G. J. Bruins, (Ed.) *Gravity Expeditions 1948–58*, vol. 5, The Netherlands Geodetic Commission, Geodetic Institute, Technological University, Delft, Kanaalweg 4, Delft, Netherlands, 111 pp., 1960, (Preface by F. A. Vening-Meinesz).

This report, which is divided into three parts, each with three different groups of authors, presents valuable and interesting gravity data, locations, and isostatic anomalies for work carried out by the Netherlands Geodetic Commission since the end of World War II. The studies reported cover submarine crossings of the Atlantic between Rotterdam, Holland, and Curacao, in 1949 and 1951, and gravity surveys of the North Sea, the Pacific Ocean area west and south of Panama, the South American coast of the Caribbean Sea, and in Surinam. A Graf land gravimeter was used for the measurements in Surinam, a North American on bottom, underwater gravimeter, for a portion of the North Sea measurements and the Vening Meinesz submarine pendulums for the other measurements. In part the results represent contributions to the program of the International Geophysical Year.

As outlined in the preface the purposes of these studies were: (a) to obtain additional data for the determination of the geoid and 'the knitting together in a consistent whole the geodetic surveys on the different continents,' (b) to obtain additional data related to the problem of the post-glacial rise of Fennoscandina and its effect on adjacent areas, (c) to ascertain if there are any special gravity features associated with the offshore area where the Andean ranges are cut off by the Caribbean coast, the submarine ridges on the floor of the Pacific Ocean southwest of Costa Rica and Panama, and the area contiguous to the Andes Mountains between Panama and Guayaquil, Ecuador, and (d) to investigate the change in gravity field associated with the transition from an oceanic to a continental type crust in Surinam.

Although the results for the first Trans-Atlantic crossing were disappointing, because of underexposure of some of the photographic records, results were obtained for sites at approximately 100 mile intervals. This spacing on a different track was used also on the second crossing, plus more detailed measurements over the Mid-Atlantic Ridge. Part I of the report, prepared by G. J. Bruins, R. Dorrestein, H. J. A. Vesseur, G. Bakker and L. Otto, presents the results for these observations plus those in the Caribbean Sea and those west of Panama in the Pacific Ocean. The data for this part of the report are interpreted by F. Vening Meinesz, who comments on the belt of marked negative isostatic anomalies mapped from 65° W longitude in Venezuela to Haiti as being caused probably by uniaxial compression of the crust in an azimuth of about N 35° E. He believes this is associated with movement of the South American continent in this direction relative to the Caribbean area. The abrupt termination of the anomaly belt near Haiti, he believes, is related to faulting on the northwest side of the moving block that coincides with the Beta Ridge and, further to the southwest, with the flexure in the Isthmus of Panama.

Many analogies are drawn with similar anomaly features in the East Indies, and the role of convection currents within the mantle is stressed as a probable primary cause in developing the anomaly pattern and the associated bathymetry observed. This applies both to the area west of the Isthmus in the Panama Basin, where positive anomalies occur, and along the Pacific and Caribbean coasts of South America, where marked negative anomalies are found.

Part II, prepared by B. J. Collette, presents the results for the North Sea measurements, and also a geologic interpretation of particular interest because it indicates that the North Sea area is essentially in isostatic equilibrium with departures related to geologic features associated with tectonic and petrologic provinces observable in the Scottish Highlands and along the coast of Norway. As the magnitude of these localized anomalies is large (-20 to $+50$ mgals) they completely mask any systematic effect, if it exists, related to post-glacial uplift. This section is also of interest because it includes the results of a direct gravity connection between Bad Harzburg (Germany), DeBilt (Holland), and Cambridge, (England).

Part III, prepared by J. Veldkamp, presents the results of the measurements in Surinam, and an analysis of these data in terms of the change in crustal structure in progressing from the ocean onto the continent. For a density contrast of 0.45 gm/cc between the crust and mantle, a reasonable fit to the observed anomaly values can be secured if a gradual change in crustal thickness is assumed from a sea level continental crust 28 km thick to an oceanic crust 7.56 km thick with 4 km of overlying water.

Maps are included showing the locations of all observation sites, the accompanying anomaly values along sections, and, for some areas, contours.

G. P. Woollard

Kinsell L. Coulson, Jitendra V. Dave, and Zdenek Sekera, *Tables Related to Radiation Emerging from a Planetary Atmosphere with Rayleigh Scattering, Univ. of California Press*, x + 548 pp. of tables, 1960, $12.50.

Here is a new and comprehensive work that will be welcomed by those of us who are interested in planetary atmospheres from a point of view midway between those of the astronomer and the meteorologist. The more than five hundred pages of numbers that compose the bulk of the book have to do with very timely problems, that is, a complete

theoretical description of the diffuse radiation lost to space and of that which is incident on the surface underlying a planetary atmosphere illuminated by an external source of a known spectrum and intensity.

These, of course, are very general problems. A comprehensive theory would have to include all the possible interactions of the incident energy with the atmosphere and the planetary solid or liquid surface, depending for example, on the nature of the surface reflection, the equilibrium temperature of the surface and atmosphere, the thermal radiation transfer in the presence of line and band absorptions within the atmosphere, and induced emissions from photochemical action, as well as the scattering mechanism per se. This is a formidable task. For an atmosphere like ours, it is reasonable to start the attack with as simple a model as possible, by assuming that the atmosphere is thin compared to the planet's radius, and is homogeneous in composition. In that case, one considers a plane-stratified atmosphere composed of air molecules that scatter the light without absorption or re-emission at a different wavelength. However, a correct formulation must include all orders of multiple, independent scattering. If furthermore, the underlying surface is made homogeneous and partially reflecting, we have the rather simple sounding problem, which is the subject of these tables. Despite this and Prof. Chandrasekhar's remarks in his lucid foreword, the simplicity, even in this case, is illusory; this author not only formulated the problem in an elegant and useful form, but also showed the way toward a complete solution. The task of applying Chandrasekhar's theory to the terrestrial atmosphere and 'feeling' the numerical magnitudes, was undertaken successfully by Prof. Sekera and his co-authors. The present tables supersede and complement previous partial tabulations by Chandrasekhar and Elbert, Sekera and Blanch, and Sekera and Ashburn.

The preface outlines the theory used, and describes the quantities tabulated in precise terms. With Chandrasekhar's *Radiative Transfer* (Oxford University Press, 1950; Dover, 1960) as a companion volume, the reader should have absolutely no difficulty using the tables. These are divided into two parts, referring respectively to the diffuse fluxes directed toward the surface and space. The total intensity of these fluxes and the relevant Stokes parameters, as well as the explicit degree of polarization and the orientation of the plane of polarization, are set down in terms of four independent parameters, namely, the direction of the external source, the optical depth of the atmosphere (which also determines the wavelength of radiation in terms of the mass of air), the direction of observation given by azimuth and elevation angles, and the reflectivity of the surface. These parameters are given at selected intervals, sufficient for graphical interpolation within the range. Numerical interpolations of all quantities with respect to the azimuth can be obtained further by means of the formulas given in the preface and the quantities tabulated in the text. All the values listed are in the form of dimensionless numbers referred to π units of external incident flux. These can be transformed easily into physical units by introducing the solar monochromatic flux density outside the atmosphere, and the appropriate solid angle corresponding to a given photometer. For example, some applications of the tables to the sunlit terrestrial atmosphere have been discussed in separate publications listed at the end of the preface.

The work as a whole has to do with one aspect of the broad subject of starlit planetary atmospheres, and it also illustrates the potentialities of the method developed by Chandrasekhar to solve the related class of mathematical problems. The tables will find many uses besides estimating the outward and inward diffuse radiation from the entire terrestrial atmosphere. For example, inward fluxes for mountain stations can be easily interpolated by properly reducing the optical thickness. Observed deviations from the theory of the measured fluxes and polarization can be interpreted in terms of absorbing layers and large particles. More important, with the new space platforms available, for the first time one can look in detail at the outcoming radiation from our own and from other planetary atmospheres. In the terrestrial case, the tables will be indispensible for estimating the scattered background continuum against which day airglow features may appear. In the planetary case, particularly with Venus and Mars, photometric and polarimetric data, obtained from a close-in probe, can be compared with the theoretical values in order to determine whether these atmospheres are composed predominantly of individual gas molecules or contain appreciable amounts of large particles in suspension.

The tables could very well be extended to higher values of the optical thickness (limited to unity in the present case) to include the case of atmospheres that are deeper than our own. Such an extension is to be hoped for. As it is, the work under review should be a valuable and usable addition in the libraries of research workers in terrestrial and planetary physics. The price of the book is quite moderate considering the effort and care invested by its authors in its preparation.

Diran Deirmendjian

R. D. Russell and R. M. Farquhar, *Lead Isotopes in Geology*, Interscience, New York, 243 pp., 1960, $9.00.

The field of isotope geology has outgrown comprehensive bibliographical reviews such as Rankama's *Isotope Geology* and now is in need of detailed review of its several fields. These fields are growing so rapidly that it is difficult for even the specialist to keep abreast of current developments. It is apparently to fill such a growing need for integration of the scattered work on lead isotopes that this book has been written. The discussion is confined principally to data obtained from samples of galena, for which the greatest quantity of data is available, but includes some discussion of lead

from meteorites, from rocks, and from uranium minerals. The second half of the book consists of a tabulation of the existing lead isotope data, which will thus be conveniently available for a while in one place.

The first two chapters contain a well-written and informative introduction to the general subject. The third chapter, on the age of the Earth, is poorly written, and consequently is difficult to understand. Some undefined notation is used, and the reader is not told, in some places, whether an average means a time or space average. Some of the important statements made in this chapter appear to the reviewer to be incorrect, but, because of the obscure presentation it is difficult to be sure of this. Readers are advised not to give up, but, rather, to first skip this chapter because the discussion of anomalous leads and lead-uranium-thorium methods of age determination that follows it, is of considerable value.

In a rapidly developing field such as this, one cannot expect a definitive work, and this book surely is not such a work; in the reviewer's opinion it falls short of the goal somewhat more than necessary. Nevertheless, it fills a need that has not been filled by any other writers, and the authors deserve credit for having made a timely contribution.

George W. Wetherill

SIMO LAURILA, *Electronic Surveying and Mapping*, Ohio State University Press, Columbus, Ohio, 294 pp., 1960, $6.00.

This text and reference book is an outstanding accomplishment and reflects the fact that the author has not only a vast scientific knowledge but also firsthand practical experience in the field of electronic surveying.

The book is divided very logically into three parts. In Part I, Dr. Laurila has reviewed the electronic fundamentals necessary to an understanding of electronic surveying systems. All the material he has included is pertinent, and is well presented in its relationship to the discussion of electronic surveying systems that comprise parts II and III.

In Part II, the author discusses, with remarkable clarity, the various systems in use today. The general principles, specific details, and accuracies of these systems are presented. Circular methods, hyperbolic methods, and other methods follow each other in orderly arrangement.

Part III includes special problems and applications basic to the operation of electronic surveying systems, and to the reduction and utilization of the data obtained by the systems. This information is, of course, vital to the proper application of the various systems to field use.

All diagrams, sketches and photographs are extremely well prepared and help to clarify the details and derivations developed in the book.

This work of Dr. Laurila's is a significant contribution to the field of electronic surveying. It is the first document I have found wherein all the systems are included. Prior to the publication of this book I had many occasions to search for background material on the performance of electronic systems such as raydist, lorac, hiran, geodimeter and tellurometer. In order to find such material I contacted, at various times, at least twenty military and government agencies, private industry and individuals. Here in one work is contained all the information I sought. Needless to say, I am highly enthusiastic that Dr. Laurila's work has been published and that it is now available for use in the classroom and in the field.

Clair E. Ewing

MARTIN J. BUERGER, *Crystal-Structure Analysis*, John Wiley and Sons, New York, xvii + 668 pages, 1960. Price $18.50.

This may be considered the culminating volume in the series of books begun 19 years ago by Professor Buerger: i.e., (1) *Numerical structure factor tables*, Geol. Soc. Am., Spec. Paper 33, 1941; (2) *X Ray Crystallography*, Wiley, 1942; (3) *The Photography of the Reciprocal lattice*, ASXRED Monograph No. 1, 1944; (4) *Elementary crystallography*, Wiley, 1956; (5, with Leonid V Azaroff) *The powder method*, McGraw-Hill, 1958; and (6) *Vector space*, Wiley, 1959. In this list No. 4 is included because it is written entirely from the point of view of the structural crystallographer, and No. 5 because the powder method has its uses even in the determination of crystal structures.

It is claimed by the publishers that '*Crystal-Structure Analysis* formulates the methods—and the theory underlying these methods—for finding the locations of atoms in crystal cells. It is designed to provide the reader who has no background in the subject with the theoretical and methodological "equipment" for handling specific analytical problems.' The author explains in the preface, and again in chapter 21, that certain aspects of crystal structure determination—among these are some in whose development he has played a leading part—have been treated separately in the 'companion volume,' *Vector Space*. Surely he would agree that his other earlier works are by no means superseded by his latest. In all but one of the first seven chapters of the present volume are references to *X-ray Crystallography* (1942), and many of these are indispensable, being references to particular derivations or figures. As the present reviewer noted (American Jour. Science, 255, 379–381, 1957) in discussing *Elementary Crystallography* (1956) 'it almost seems that he (Buerger) chose to leave out everything that has been adequately dealt with before.'

In the preface to the present volume two omissions having a different basis are explained by the author. The subject of reflection statistics is omitted, and it is stated that it 'deserves to be treated in a separate monograph by an expert in statistics.' Similar remarks might be made regarding the determination of crystal structures by means of tools other than

x-ray diffraction, and regarding the study of the numerous types of disorder that may exist in crystals. 'The subject of optical Fourier transformers,' is omitted because it is the author's opinion that 'the use of optical analogue methods is waning.' In spite of these exclusions this book covers the essentials of crystal structure determination far more fully than any other.

The scope of the book can best be suggested by enumerating the chapter headings: (1) Introduction, (2) Some fundamental diffraction relations, (3) Some quantitative aspects of the diffraction of x-rays by crystals, (4) Outline of a crystal-structure analysis, (5) Selection of material suitable for crystal-structure analysis, (6) Measurement of intensities, (7) Some geometrical factors affecting intensities, (8) Some physical factors affecting intensities, (9) The number of atoms in the unit cell and their distribution among the equipoints, (10) The structure factor, (11) Plane projections in structure-factor calculations, (12) Examples of the determination of some simple crystal structures, (13) Fourier synthesis, general theory, (14) Forms of Fourier syntheses useful in crystal-structure analysis, (15) Reciprocal space, (16) Symmetry in reciprocal space, (17) Application of symmetry to Fourier summations, (18) Practical methods of summing Fourier series, (19) Phase determination for structures having a set of heavy or replaceable atoms (20) Phase determination for certain special cases, (21) Direct determinations, (22) Refinement, (23) Calculation of interatomic distances and angles, Index 33 pages.

The first chapter is devoted to historical background—a most welcome touch; here, however, the author has allowed his enthusiasm to carry him away at one point. The 1951 congress in Stockholm was not 'attended by some 3000 members,' as he states on page 4, but by 'about 340 crystallographers and some 70 passive members' (*Acta Cryst.* 4, 566–567, 1951). The treatment throughout is very thorough, and has many original features. Nearly every subject is developed extensively or even exhaustively. Not only are mathematical derivations given fully, but in some cases, also, alternate derivations are offered, and a great deal of space is given to practical considerations and to examples at various levels of difficulty. For the uninitiated this thoroughness may actually have disadvantages. Formal treatment of such a fundamental matter as the meaning of F_{hkl}, an understanding of which is required in dealing with even the simplest crystal structure problems, is not taken up before page 259, though it is referred to in a preliminary fashion in chapter 2. In Lipson and Cochran's *The determination of crystal structures* (London, 1953), which has hitherto been, by far, the leading text in the field, this topic appears early, on page 10. An even more striking example of the difficulty of organizing the complex maze of material covered by this book is the fact that treatment of the reciprocal lattice, that indispensable tool of x-ray crystallographers, is postponed to chapter 15, p. 407. A guide through this maze is furnished by the brief chapter 4 in which the organization of the book is explained with specific reference to the relations among most of the other chapters.

The book includes a number of features that one has come to associate with the works of Buerger published by Wileys. Again, the end papers contain representations of the 17 plane groups, arranged in exactly the same order as in three predecessors, but executed in a different manner each time, this time to show 'the symmetries in reciprocal space corresponding to the 17 plane patterns.' Besides footnote references, which are concerned only with specific points, each chapter except two and four is concluded with a list of references. Several of these are complete up-to-data bibliographies, classified under subheadings of the chapter's subject. As was to be expected, the longest of these bibliographies appears at the end of chapter 21, on *Direct determinations*; it includes 138 titles from 1927 to 1959, grouped under eight subheadings.

Some of the material in tabular form, as, for example table 2, chapter 11, *Projections of space groups*, is conveniently available elsewhere. This table covers only the space groups of the triaxial systems, that is, those covered by the International Tables. An extension to the remaining 156 space groups would be useful. In this table Buerger uses the so-called 'first setting' for monoclinic space groups, but in several other places he has used the officially approved traditional setting.

Many of the points covered by this book are treated in a novel manner, some have been neglected by other authors of textbooks, and a few have never been dealt with fully at all. For example, other writers have not taken the trouble to give formulas for calculating interatomic distances and angles in each of the systems (chapter 23); also, 27 pages, comprising many tables and figures, are devoted to the problem of absorption, which is usually disposed of with a few words. So far as known to this reviewer, chapter 5, *Selection of material suitable for crystal-structure analysis*, has no counterpart in other books; in this chapter, among other things, the effect of twinning on x-ray diffraction patterns and their interpretation is set forth. Here, as in many places, the author has been able to draw on his own earlier work, and x-ray crystallographers should rejoice that all of this valuable material has been assembled between two covers and placed in its proper relation to the entire field.

A. Pabst

BENJAMIN F. HOWELL, JR., *Introduction to Geophysics*, McGraw-Hill Book Co. Inc., New York, 399 pp., 1959, $9.00.

Professor Howell has set himself the formidable task of presenting a broad view of geophysics in one tidy volume. To be sure, he has simplified matters somewhat by his self-imposed restriction of the treatment to solid-earth geophysics, with only incidental reference to the physics of the atmosphere

and the oceans. But even so, it has required careful judgment in the selection of topics and in the manner of dealing with them.

Long ago the author became aware of the dearth of suitable textbooks, in English, on general geophysics as opposed to such specialized subdivisions as geophysical prospecting or seismology. The present volume is intended to fulfill this need. In his Preface, the author describes his aim as follows:

> 'This work was written as a beginning college textbook in geophysics. Its principal objectives are to familiarize the reader with the scope of geophysics in relation to the other sciences, to give him some insight into the methods used by geophysicists to study the earth, and to outline some of the most important discoveries of these researches. .... The lack of a comprehensive introductory text led to the present work. It has been written with a course composed half of juniors and seniors and half of graduate students in mind. .... The book is intended to satisfy the needs of a broad range of specialists for a basic knowledge of the fundamental principles of geophysics. It is assumed that the student using the text will be familiar with the terminology of both geology and physics. One semester of geology and one year of college physics should be sufficient preparation for understanding of the ideas presented here.'

In an effort to make the work palatable to a wide circle of readers, the required mathematical background is kept to a minimum. A knowledge of elementary calculus is sufficient, except in a few cases—such as the section on the transmission of seismic waves—where somewhat more complex mathematics is involved.

An impressive array of subjects is brought together between the covers of one volume, as may be seen from the list of Chapter headings: *Origin of the Earth*; *Origin of the Moon*; *Geochronology*; *Temperature of the Earth*; *Seismic Waves*; *Observational Seismology*; *Cause of Earthquakes*; *Instrumental Seismology*; *Transmission of Seismic Waves*; *Data Derived from Seismology*; *Mass, Moment, Shape, and Size of the Earth*; *Density and Elastic Constants*; *Measurement of Gravity*; *Isostasy*; *Tectonic Forces*; *Origin of the Continents*; *Continental Drift*; *Tectonic Patterns*; *Typical Tectonic Profiles*; *Cause of Mountain Building*; *Geomagnetism*; *Terrestrial Electricity*; *Geomagnetic and Geoelectric Instruments*.

In the chapters on geomagnetism and terrestrial electricity, the author departs somewhat from his basic plan of dealing with only the solid Earth. The reason is that a full understanding of the variation of the Earth's magnetic field requires some knowledge of the electrical currents that flow in the atmosphere and the oceans as well as in the solid body they surround, these currents, of course, being intimately related to the nature and cause of the magnetic field.

On such subjects of perennial controversy as the origin of continents, continental drift, and the causes of mountain building, the author touches lightly but informatively. Not all authorities in these and some other fields will agree entirely with his emphasis, or possibly even his treatment, of these great questions, but it seems to the reviewer that Professor Howell has given a fair and useful summation of present thinking in these subjects.

It is stated in the Preface that the book is intended for reference as well as for textbook purposes. To this end, an extensive bibliography is included so that the attention of the reader may be directed readily to more detailed treatments of the various subjects. The bibliographic items consist in large part of books or of summary papers, which in turn will supply a wealth of references to original sources.

As a textbook for undergraduates and as a reference source for geophysics of any status this book will doubtless find a wide use.

Leason H. Adams

H. E. Landsberg and J. van Meighem (Eds.), *Advances in Geophysics, Vol. 5* Academic Press, Inc., New York, 325 pp., 1958, $10.00.

The present volume, like the preceding volumes of this series, covers a selected list of topics in several fields of geophysics. It is only natural that much of the work detailed in the current volume has been inspired by, or is closely related to, that extraordinary program of world-wide collaboration known as the International Geophysical Year (IGY). Indeed, the first section by N. C. Gerson, is entitled 'From Polar Years to IGY,' and offers a compact summary of the history, development, and broad accomplishments of this venture in international cooperation.

It was the vision and zeal of Karl Weyprecht that led to the original International Polar Conference, and later to the First International Polar Year, which, in the course of a 13-month period beginning in 1882, succeeded in obtaining a large variety of useful results from its 12 expeditions to the Arctic and 3 to the Antarctic. This paved the way for the more comprehensive second Polar Year, beginning fifty years later, and finally for the tremendous international scientific program of the IGY of 1957–1958. This program has provided a fantastic amount of new information in all fields of geophysics, and the very magnitude of the mass of recent data has given rise to apprehensions that our geophysical thinking may be impeded by a surplus of undigested facts. In this, as in other branches of science, it may be vital to encourage, for a while, a shift in major emphasis from data gathering to data analysis. As stated neatly by the Editors in their Foreword, 'Indiscriminate amassing of observations will retard rather than advance science.'

It is gratifying to note that the articles in Volume 5, like those in the preceding volumes of the series, are important steps toward the analysis and consolidation of our rich store of geophysical informa-

tion. Here, six different phases of geophysics are treated. It may be recalled that the first four volumes contain a total of 25 sections. In addition to the first Section of this Volume by Gerson, there are five others: *Microseisms*, by the late B. Gutenberg; *The Size and Shape of the Earth*, by R. A. Hirvonen; *Oceanic Tides*, by A. T. Doodson; *Ultraviolet Absorption Processes in the Upper Atmosphere*, by K. Watanabe; and *The Physics of Cloud Formation*, by James E. McDonald. The several authors are well qualified to deal authoritatively with their subjects, and the treatments are uniformly informative and well rounded. It will be found that the discussions of recent advances are stimulating, and that various new techniques are carefully evaluated.

Each section is preceded by a detailed table of contents, and the authors have annotated their contributions by ample bibliographies of pertinent scientific work that provide a total of nearly 800 references. Furthermore, the reader will appreciate the complete subject index and author index, as well as the cumulative title index to the preceding volumes and the cumulative subject index.

Altogether, the content, the treatment, and the style make this a valuable and usable volume.

Leason H. Adams

N. V. Glazov and A. N. Glazov, *New Instruments and Methods of Engineering Geology*, 91 pp., translated from Russian Consultants Bureau, Inc., New York, 1959, $3.25.

A more appropriate title for this informative little work would be *Geophysical Instruments and Methods for Soil Mechanics*. Most of its 91 pages are devoted to descriptions of instruments and techniques for investigating the engineering properties of soils and the location and movement of underground water. Although much of this information will be useful to students in applied geology, the emphasis is primarily on investigating procedures that are of interest chiefly to soil scientists and soil mechanics engineers.

The use of mechanical and radiometric methods for determining soil properties, such as natural moisture, density, porosity, and solubility, and the location and flow of underground water, are the principal topics discussed. Among the techniques described are measurement of sediment transportation, neutron probes for soil moisture, gamma ray absorption measurements of soil density, density determination by the Pelletier piston-type densimeter, use of the Photoburoscope (borehole camera), and use of the radioactive densimeter for remote measurements of liquid densities. Most, if not all, of these techniques have been either tried or put to practical use by leading private and public geotechnical organizations in the United States and Europe. Needless to say, considerable precaution must be exercised in the extent to which such instruments and techniques are substituted for the conventional and more reliable laboratory testing of soil properties through the use of undisturbed samples.

The scintillation counter, employing the principal of photocathodic reflection of electrons converted to a pulsating current, is one of the more impressive techniques for determining soil moisture that are described by the authors. The number of beta rays flashed to the detector used with the scintillator is proportional to the moisture content of the soil surrounding the neutron source. To quote the authors, 'The advantage of this method is that neutrons detect water (hydrogen atoms) regardless of whether the water is in the liquid, gaseous, or solid state.' Thus, its usefulness in permafrost country is obvious.

Engineering geologists will be disappointed in the relatively subordinate position given by the authors to discussion of the latest developments and improvements in methods for investigating the mechanical properties of rocks as foundations or construction materials. With the rapid advances we have experienced during the past five years in the field of rock mechanics and bedrock exploration, a chapter or two on these subjects would have enhanced the usefulness of this text as a reference for students in engineering geology.

The authors, scientists in the USSR All-Union Scientific Research Institute of Hydrogeology and Engineering Geology, are to be complimented for a lucid discussion of the topics covered and for a very acceptable bibliography.

Robert H. Nesbitt

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Note—Starting with the March 1959 issue of the *Transactions*, the contents of *Izvestiya*, Geophysics Series, for 1957–1960, are to be found in successive issues.

The production of the English edition has been undertaken with the aid of a grant from the National Science Foundation starting with the series for 1957. Orders for sets for 1957, 1958, 1959, and 1960 ($25.00 for each set of twelve numbers) should be sent to the American Geophysical Union. Individual numbers are available for $5.00 each. Subscriptions are now being received for the 1960 series at a price of $25.00 for the year.

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Determination of the stresses active in the foci of earthquakes, based on observations at seismological stations, A. V. Vvedenskaya, 7 pp.

Integral methods for interpreting anomalies ΔZ having like signs, V. N. Strakhov, 10 pp.

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On determining the elements of a seismic ray from the data of a single station, by G. D. Panassenko, 9 pp.

Temperature field in front of protruding capes, Yu. F. Vasil'ev and S. M. Popov, 9 pp.

Results of investigations of natural aerosols over the various regions of the U.S.S.R., A. G. Laktionov, 9 pp.

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Features of the growth of hail by coagulation related to the variation of the velocity of the vertical current at high altitudes, N. Sh. Bibilashvili, V. F. Lapcheva, A. A. Ordzhonikidze and G. K. Sulakvelidze, 9 pp.

On certain results obtained from the study of vertical gradients of a magnetic field in the area of the Kursk magnetic anomaly, M. I. Lapina, 7 pp.

Earth's magnetic field as the sum of fields of two dipoles, B. M. Lyakhov, 6 pp.

The general solution of an axially symmetrical problem in induction logging theory, V. N. Nikitina, 10 pp.

The determination of the anisotropy coefficient and the angle of depression of a homogeneous anisotropic medium, by measuring the impedance of the natural electromagnetic field, D. N. Chetaev, 3 pp.

An airplane condensation hygrometer with the automatic recording of dew point, A. M. Gromov, 6 pp.

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Symposium on Radiation at Oxford, England, 2 pp.

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On the determination of the energy of elastic waves generated by earthquakes, E. F. Savarensky, N. V. Kondorskaya, and V. L. Belotelov, 9 pp.

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On the statistics of transformations in a radioactive series, R. M. Kogan, 8 pp.

On vertical fluctuations of the water temperature in the Black Sea, N. T. Glinsky, 10 pp.

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Photoelectric observations of pulsating forms of auroras, N. V. Georgio, 6 pp.

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Bore-hole percussion device for the excitation of various types of elastic waves, O. I. Kovalev and L. V. Molotova, 11 pp.
The use of magnetic powder in studying the composition of iron cores, M. A. Grabovsky, O. N. Zherdenko and Yu. P. Skovorodkin, 4 pp.
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Contents of Geodesy and Cartography, U.S.S.R., March—August, 1959

Note—Starting with the December 1960 issue of the *Transactions*, the contents of the English translation of *Geodesy and Cartography* will appear in successive issues.

Publication of an English edition of this leading monthly journal of Geodesy and Cartography in the USSR has been undertaken with the aid of a grant from the National Science Foundation, starting with Number 1 (January) of the 1959 volume. A volume set of 12 numbers is priced at $20.00, and orders should be sent to the American Geophysical Union. Individual numbers are available for $5.00 each. Subscriptions are now being received for the 1959 volume.

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Spectral, electrophotometrical and radar researches of the aurorae and airglow: (collection of articles); LC or SLA, mi $4.50, ph $12.30 [*Spektral'nyye, Elektrofotometricheskiye i Radiolokatsionnyye Issledovaniya Polyarnykh Siyaniy i Svecheniya Nochnogo Neba, Moscow*, 1959].

Transactions of the Main Geophysical Observatory: selected articles, LC or SLA, mi $3.90, ph $10.80 [*Glavnaya Geofizicheskaya Observatoriya, Leningrad, Trudy, USSR*, no. 72[134], 33–38, 110–138, 1957].

Notes and Personalia

Notes

• CORRIGENDUM—E. H. Vestine has called attention to corrections to Table 2 of his paper, *The Survey of the Geomagnetic Field in Space*, in the March 1960 issue of the *Transactions*, page 18, listing spherical harmonic coefficients of the geomagnetic field for 1945.0 obtained by Fanselau and Kautzleben. The corrections are as follows:

Column	Line	
1	4g	for +77.40 read +77.44
5	13g	for − 0.27 read + 0.56
6	13g	for − 0.77 read − 0.27
7	8g	for + 1.02 read + 1.03
7	13g	for + 0.77 read − 0.77
7	10h	for + 0.61 read − 0.61
8	15h	for − 0.48 read − 0.47

• SITE CHOSEN FOR ATMOSPHERIC RESEARCH CENTER—The National Science Foundation has approved Table Mountain, near Boulder, Col., as the site for the headquarters of the new National Center for Atmospheric Research. Selection of the site was made after an extensive study by the University Corporation for Atmospheric Research, which will also manage the Center for the NSF. This Corporation is composed of representatives of thirteen colleges and universities that grant degrees in Meteorology, comprising of the following institutions: University of Arizona, University of California, University of Chicago, Florida State University, The Johns Hopkins University, Massachusetts Institute of Technology, University of Michigan, New York University, Pennsylvania State University, St. Louis University, Texas Agriculture and Mechanical College System, University of Washington, and the University of Wisconsin.

Many criteria governed selection of the site. Because no single location could afford access to all the varied phenomena likely to be studied, supplementary field stations will probably be established elsewhere in the United States as the program developes. However, it was felt that the Table Mountain location would satisfy more of the principal criteria of versatility with respect to meteorological phenomena, general accessibility, proximity to collateral research centers, variability of regional physical features, and central location, than would any of the other sites that were investigated during the two year study.

The purpose of the Center will be to assist research institutions in promoting knowledge and understanding of the atmosphere and of the physical processes that govern its behavior. The Center will be particularly concerned with fundamental studies on a planetary scale. The background of its conception and statement of its needs and aims were discussed in a summary article, 'A National Institute for Atmospheric Research', by Thomas F. Malone, President of the Section of Meteorology, and published in the June 1959 issue of *Transactions*.

• LINEAR STRAINS IN EARTH'S CRUST BEING MEASURED—Scientists of the Lamont Geological Observatory of Columbia University have started on a project to determine whether the Earth's Crust shrinks or stretches over a long period of time. A special linear-strain seismograph, sensitive enough to record a change of a small fraction of an inch in the crust between New York and Chicago. The instrument has been installed 1850 feet below the surface in an old exploratory tunnel of a mine of the New Jersey Zinc Company at Odgensburg, in northwestern New Jersey, a stable area where there are no mountains and for which there is no record of earthquakes. A component of the instrument is a cylindrical rod of quartz, 200 feet long, and two inches in diameter, one end of which is attached to the Earth. The rod is supported by slings spaced ten feet apart. Devices on the floor detect motion, and are connected to instruments that record Earth movements continuously.

According to Jack E. Oliver, seismologist at the Lamont Observatory of Columbia University, three such instruments will be necessary to measure the contraction and expansion of the Earth's crust and record the crustal tides. Accordingly, preliminary work has been started on another instrument for

determining a second horizontal component, and on a third instrument—to be forty feet high—for the vertical component. The seismograph is patterned after one designed by Hugo Benioff of the California Institute of Technology.

The instrument is expected to provide, also, data on 'tides' in the solid Earth. As in sea tides, the Moon plays a major part in Earth tides, which sometimes cause a rise and fall of about half a foot in 12 hours.

Dr. Oliver reported that the new seismograph supplied a fine record of the disastrous Chilean earthquakes, that the entire globe appeared to have quivered, and that the seismographs provided the first instance in which free vibrations are known to have been observed.

● GLOBAL WEATHER COMMUNICATIONS NETWORK—An improved global network of point-to-point radio teletypewriter and hand-line teletypewriter circuits to coordinate exchange of weather information will, when completed, embrace five communication centers in the Northern Hemisphere. The first phase of the Network began operations on October 1, 1960, activating centers at New York, Frankfurt, Moscow, and New Delhi. The second phase, activated in the spring of 1961, will add the Tokyo center, and so provide for completely coordinated exchange of data for the entire Northern Hemisphere.

A third phase of the program will establish a similar network in the Southern Hemisphere, thus permitting a world-wide exchange of weather information.

Organization of the system is the result of several years of coordination and planning. The establishment of this exchange is a milestone in the advancement of objectives of the World Meteorological Organization, according to Paul H. Kutschenreuter of the U. S. Weather Bureau and President of the WMO Commission for Synoptic Meteorology, under whose direction the program has evolved. Through participation in the WMO, members of the Weather Bureau have contributed in large measure to the improvement of weather services throughout the World, and the coordination of data collected under this activity has been of great value to the United States.

● CHILEAN EARTHQUAKE CAUSED EARTH TO 'RING'—A jolt such as the recent Chilean earthquake of last October causes the Earth to 'ring' like a bell, according to scientists of the Seismology Laboratory of California Institute of Technology. A highly sensitive seismograph designed by Hugo Benioff of that institution, and known as an *extensometer*, can record the very slow natural vibration of the Earth, of a little less than one per hour, that can be heard only by being recorded and speeded up. The lowest tone audible to humans is about four octaves below middle C, whereas the Earth's natural vibration frequency is about 20 octaves below. The Earth's overtones have frequencies up to 3.7 minutes and are confined to the shallower layers. However, these die down faster than the fundamental vibrations, which continue much longer in the Earth's core, and so may be detected without interferences. The vibrations from the Chilean earthquake continued for about two weeks.

Analysis of the oscillations is reported to have enabled the CIT seismologists to 'map' the fault action that caused the earthquakes; the fault movement was horizontal and was mostly under the sea. The analysis is also said to provide considerable support for the Gutenberg model of the Earth's structure.

● R. V. CHAIN RETURNS FROM 5-MONTH CRUISE—The research vessel *Chain*, of the Woods Hole Oceanographic Institution, returned to home port on November 12, 1960, after a five-month cruise to make observations chiefly in the North Sea, the Norwegian Sea, and the British Isles. The ocean waters, bottom sediments, and underlying crust were studied. Scientists from several European nations were aboard, and many seismic observations were made at locations suggested by them, to help in their own research projects. Also, during several parts of the cruise, American scientists of the *Chain's* research staff worked with staffs of the Norwegian research vessels *Helland-Hansen* and *H. U. Sverdrup*, the British *Discovery II*, and the Scottish *Explorer*. One feature of the cruise was the almost continuous use of the thermistor chain; this 600-foot long line tows an instrument to get continuous temperature readings from the upper water layers. The thermistor was towed nearly 20,000 miles, including both Atlantic crossings. On crossing the Mid-Atlantic Ridge, bottom samples and photos were obtained, and measurements were made of the heat flow from the Earth's interior.

● EAST PACIFIC RISE ONE OF LARGEST EARTH STRUCTURES—Expeditions of the Scripps Institution of Oceanography during the International Geophysical Year gathered evidence that the East Pacific Rise is one of the largest structural features of the Earth's crust. This curved ridge extends for about 8000 miles, from near New Zealand to the coast of Mexico where it disappears, perhaps beneath the western part of North America. The highest part of the crest rises two miles above the Pacific floor. The Rise is part of a system of shoal areas that occur in all oceans and of which the Mid-Atlantic Ridge is an arm. In general, the crests of these ridges lie approximately in the centers of the ocean basins, but the East Pacific Rise lies mostly at the eastern edge of the Pacific. Hawaii lies west of the westernmost edge of the Rise, and the sea-floor slopes downward gently, from the California coast. The Rise is considered to be a fairly recent feature of the Earth's crust.

● PROJECT MERCURY WEATHER NETWORK ESTABLISHED—The NASA and the U. S. Department of Commerce have announced that the U. S. Weather Bureau has undertaken the meteorological support for Project Mercury, this Nation's initial manned space flight program. The Bureau's Office of Meteorological Research will provide weather information through a special group headed by Kenneth M. Nagler. Forecasts will be made of winds, cloudiness, visibility, and state of the sea for all areas beneath the proposed orbit, and particularly for the central

Atlantic Ocean. Headquarters for the group are in Suitland, Maryland, adjoining the Bureau's National Meteorological Center. Special units are located in Miami and Cape Canaveral. In addition, data on surface and upper air analyses are transmitted to the Suitland unit from various meteorological centers in Africa, Australia, and the Western Pacific. The Miami unit will develop methods for preparing and transmitting composites of weather radar pictures in the Florida and Caribbean areas for use in predicting weather in the launch and recovery zones.

● SUMMER INSTITUTES FOR TEACHERS OF SCIENCE—The National Science Foundation has made grants totalling $22.7 million to 260 colleges and universities, in support of institutes during the coming summer for college and high school teachers of science, mathematics, and engineering. These summer institutes were started in 1953, and have, so far, provided about 54,000 opportunities for teachers to refresh their knowledge of fundamentals, to acquaint themselves with recent developments, and to learn new approaches in presenting subject matter. Usually about 50 applicants are accepted for each session, commonly lasting six to eight weeks.

Tuition and fees, allowances for travel, stipends of not more than $75 a week, and allotments for dependents (not exceeding four in number) are provided. Inquiries and applications should be addressed to directors of the institutes; a list of these is available from the National Science Foundation, 1951 Constitution Avenue, N. W., Washington 25, D. C.

● TETHYS EXPEDITION FINDS OCEANIC BIOLOGICAL DESERT—The recent Tethys Expedition of Scripps Institution of Oceanography has reported a 'biological desert' in the ocean area southeast of Hawaii and extending nearly to the mainland of the United States. The area lies under an atmospheric subtropical high pressure cell with generally calm winds. Lying between a region of traveling storms and seasonal temperature changes on the north, and the great equatorial current systems of the south, the stability and temperature stratification of the area are not conducive to the stirring actions that ordinarily serve to bring nutrients from the bottom of the ocean to favorable biological levels; consequently only near coastlines is the water notably productive. The amount of living matter captured was found to increase sharply within 300 miles of the coast.

● NYU METEOROLOGISTS RECEIVE NSF GRANT FOR RESEARCH—The National Science Foundation has made a grant of $198,200 to three meteorologists of New York University. Ben Davidson and E. L. Fisher, of the College of Engineering, and J. E. Miller of the Department of Meteorology and Oceanography, will make a pioneering study of the interaction of large- and small-scale weather processes. They will attempt to relate the behaviour of the near-ground atmosphere in small areas with behaviour at higher levels over large areas, a linkage of atmospheric processes that heretofore has not been explored sufficiently. It is expected that the results of this research may solve some of the basic problems in weather prediction.

● 'ASTROGEOLOGY' PROGRAM FINANCED BY NASA—The Department of the Interior has announced a program of research work in 'Space Geology' totalling $205,000, the funds being provided by the National Aeronautics and Space Administration for use by the Geological Survey. The Program includes geologic analysis of photographs of selected areas on the Moon; terrestrial crater studies; investigations into the origins and compositions of tektites, meteorites, and related materials of possible impact origin; and experimental studies of the mechanics of impacting objects. A reconnaissance terrane study of the Moon was completed late in 1960 for the U. S. Army Corps of Engineers; the new studies will be, in part, a continuation and expansion of that project.

● NEW ENCYCLOPEDIA OF SCIENCE AND TECHNOLOGY—A new and comprehensive encyclopedia of Science and Technology has recently been released by the publishers, McGraw-Hill Book Company. The work, which has taken five years to prepare, contains more than 7000 authoritative articles, written by more than 2000 contributors under the supervision of 63 prominent consulting editors. It covers all fields of Life Science, Physical Science, Earth Science, and Engineering, and the major applications of these fields in other technologies. It contains extensive bibliographies, and has an index of more than 100,000 entries. The price of the set comprising 15 volumes is $175.

● NEW SEISMIC RESEARCH STATION AT FORT SILL—As part of Project Vela-Uniforms, of the U. S. Department of Defence, Advanced Research Projects Agency, a new seismic research station will be established at Fort Sill, Oklahoma. It will be known as Wichita Mountains Seismological Observatory, and will fulfill conditions outlined by the Conference of Experts that met at Geneva in 1958 to study means of detecting nuclear tests in violations of a possible agreement to suspend such tests. Delegates of The United States, the United Kingdom, and the USSR, who are now negotiating in Geneva relative to a treaty to control cessation of testing nuclear weapons, will be permitted to evaluate the station's performance.

The station is designed to study the detection of earthquakes as well as of underground chemical and nuclear explosions.

● 'PLANET EARTH' FILM SERIES AVAILABLE—The National Academy of Sciences has announced the availability of its 'Planet Earth' series of films to educational and research institutions. The series synthesizes Man's knowledge of his physical environment, and delineates the new instruments for world-wide gathering of data on space and the cosmos. The films range in content from early to current experiments, with some projection into the future. Hugh Odishaw of the Academy is Director of the series, which was produced in cooperation with the WGBH Educational Foundation, Cambridge, Mass. The films will be distributed by McGraw-Hill Book Co., and are available for

preview at McGraw-Hill Text-Films, 330 W 2nd St., New York City.

● NEW WEATHER FACSIMILE NETWORK IN OPERATION—The U. S. Weather Bureau is now transmitting weather maps and analysis, by wire, twice as fast as formerly, owing to development of a new National Weather Facsimile Network. More than 100 maps are sent every day to nearly 1150 government, military, and commercial organizations and individuals. Time has also been reserved in the 24-hour schedule for transmission of cloud analyses based on photographs taken by the satellite, Tyros II.

● M.I.T. REVISES CURRICULUM FOR EARTH SCIENCES—Beginning in 1960, the Massachusetts Institute of Technology has established a common core undergraduate curriculum for the Earth Sciences, embracing Geology, Geophysics, Meteorology, and Oceanography. Specialization will come through selections of electives in the upper years. This pattern serves to broaden the undergraduate base, and to leave the bulk of specialization to the graduate years. It is expected to also stimulate closer integration of faculty efforts in these sciences. The new Center for Earth Sciences will be a 20-story building, a gift of Cecil H. Green, 1923, and Mrs. Green, that will provide ample space for all the instructional and research activities in these departments.

● UNESCO PLANS MARINE SCIENCES PROGRAM—The United Nations Educational, Scientific, and Cultural Organization (UNESCO) is planning an important project on marine science for its 1961–62 program. Together with the Special Committee on Oceanic Research (SCOR), UNESCO will co-sponsor the International Indian Ocean Expedition—the largest oceanic expedition ever undertaken so far—which will involve 14 nations and 20 oceanographic vessels. An Intergovernmental Oceanographic Commission will be set up for the program, for which secretariat services will be provided by an Office of Oceanography in UNESCO's Department of Natural Sciences.

● INDUSTRIAL EMPLOYMENT OF SCIENTISTS AND ENGINEERS GAINED IN 1960—Preliminary data released by the National Science Foundation show that employment of scientists and engineers in industry rose nearly 7 percent during 1960, as compared with 5 percent in 1959. The proportionate increase was greatest for physical scientists, but the growth in numbers of engineers exceeded that of other groups. Nearly 40 percent of the engineers and scientists were engaged in research and development activities, a significant increase in this field over the previous years.

● ANTARCTIC RESEARCH COOPERATIVE PROGRAM—The United States Antarctic Research Program, which is administered by the National Science Foundation, has included a cooperative project with Chile, during the past few months, for establishing a geomagnetic observatory at Chile's Presidente Gabriel Gonzales Videla station, and for continuing geologic studies on the Palmer Peninsula. In return for supplementary equipment for the geomagnetic station, the Chilean government has provided transport and helicopter support to the U. S. research expeditions on the Peninsula.

● RADIO ASTRONOMY INSTITUTE AT STANFORD—The Air Force Office of Scientific Research is sponsoring the new Radio Astronomy Institute that has been established at Stanford University to promote an expanded research program in which distinguished visiting scientists will participate. An advisory committee of specialists from the Stanford Electronics Laboratories and the Radioscience Laboratory will assist the Director, Ronald N. Bracewell, in administering the Institute.

● NEW SCIENCE CENTER FOR YALE UNIVERSITY—A new center to be known as the Kline Scientific Center will be constructed at Yale University, as a result of a gift of $10 million from C. Mahlon Kline of Philadelphia, a graduate of Sheffield Scientific School. The Center will embrace a chemical laboratory, a library and laboratories for biological sciences, a building for the Department of Geology, and an auditorium for the Sciences.

● NSF GRADUATE LABORATORY DEVELOPMENT PROGRAM—The National Science Foundation announces that the next closing date for receipt of proposals is Sept. 1, 1960. The purpose of the grants is to aid educational institutions in modernizing, renovating, or expanding graduate-level basic research laboratories. Eligible departments must have a graduate training program leading to doctorates in science. The institution must provide at least 50 per cent participation with funds of non-Federal derivation. Proposals, or requests for additional information, should be addressed to: Office of Institutional Programs, National Science Foundation, Washington 25, D. C.

● NEW ATMOSPHERIUM–PLANETARIUM AT UNIVERSITY OF NEVADA—Under a grant of $175,000 from the Max C. Fleischmann Foundation of Nevada to the Desert Research Institute, an Atmospherium–Planetarium is being constructed and equipped at the University of Nevada. The Atmospherium, a new idea for the display of cloud motions and weather phenomena, is the first of its kind, according to Wendell A. Mordy, Director of the Institute. It will be used for the entertainment and instruction of the general public, as well as for academic instruction in the fields of atmospheric physics and astronomy.

● SMOG WARNING NETWORK ESTABLISHED—A new network operated cooperatively by the Weather Bureau and the Public Health Service gives advance warning of impending severe smog conditions to cities of 36 States east of the Rocky Mountains. Bulletins are sent by teletype from the Weather Bureau Research Station, in Cincinati.

● SOCIETY OF EXPLORATION GEOPHYSICISTS MEETING—More than 500 geophysicists are expected to attend the 14th annual midwestern meeting of SEG, to be held in Oklahoma City, April 9–11, 1961. The theme of the meeting is 'Geophysics and Economic Oil Finding', and a display of early day geophysical instruments will highlight the event.

● CHESAPEAKE BAY SHORELINE SURVEY IN PROG-

RESS—The Coast and Geodetic Survey, in cooperation with the State of Maryland, is making a 1500-mile survey of the Chesapeake Bay shoreline. Thirty-seven special maps, and a revision of about 80 of its large scale base maps of the area, are involved. The cost of the project will be approximately $120,000, shared equally by the State and Federal Governments.

• SEGP FOUNDATION SCHOLARSHIPS AWARDED—Twenty-nine students have enrolled in colleges for the 1960–61 school year, with $19,000 in scholarships awarded by the Society of Exploration Geophysicists Foundation. The Society's scholarship program was started in 1955, and is continued by the Foundation, which was established in 1955 to administer a trust for scholarships and research in fields of interest to petroleum exploration.

• AWARDS FOR ESSAYS ON GRAVITY—The Gravity Research Foundation will make five awards for short essays, (approximately 1,500 words), for the purpose of stimulating thought and encouraging work in harnessing gravity. The awards range from $1000 to $100. Typewritten essays, double-spaced, with two carbon copies, and accompanied by a title covering the area of thought of the essay, a summary of 100 words or less, and a separate sheet with a short biographical sketch, must be received before April 15, 1961, at Gravity Research Foundation, New Boston, New Hampshire.

• CONFERENCE ON GREAT LAKES RESEARCH—The Fourth Conference on Great Lakes Research will be held in the Rackham Building in Ann Arbor, Michigan, on April 17 and 18, 1961. The conference will be sponsored by the Great Lakes Research Division (formerly Great Lakes Research Institute) of the University of Michigan's Institute of Science and Technology. The Proceedings will be published, and inquiries regarding publication or presentation of papers, or further information, may be addressed to the General Chairman, Dr. Charles F. Powers, Great Lakes Research Division, 1119 Natural Science Building, Ann Arbor, Michigan.

• NSF SENIOR POSTDOCTORAL FELLOWSHIP PROGRAM—The National Science Foundation will reopen its Science Faculty and Senior Postdoctoral Fellowship programs in May, for awards to be made in December 1961. For fiscal 1961 the NSF granted 376 fellowships in the two programs.

• NSF GRANTS OFFER RESEARCH OPPORTUNITIES TO SCIENCE TEACHERS—As in the previous two years, college and secondary school teachers will be encouraged to participate in research in 1961, under grants made by the National Science Foundation. For college teachers, a Master's or a Doctor's degree will be required for participation, and the work must be done in a department that offers the doctorate; stipends are $100 a week (plus allowances for travel and dependents) for those holding doctor's degrees, and $75 a week for holders of Master's degrees. Most of the research is to be carried out during the summer. Secondary school teachers must hold, or qualify for, the Master of Science degree; they will receive stipends up to $75 a week (plus allowances for travel and dependents), and the programs will be for eight to twelve weeks in the summer. A list of cooperating institutions is available from the National Science Foundation, 1951 Constitution Ave., N. W., Washington 25, D. C., but inquiries and applications should be addressed to the directors of the programs at the institutions.

• INQUA MEETING IN POLAND, AUGUST AND SEPTEMBER, 1961—The International Association for Quaternary Research (INQUA) will meet in Poland during the late summer of 1961. The Congress, which meets every four years, will be preceded by an excursion to start from Warsaw on August 27. The Congress will meet from September 2 to September 7, both inclusive. A post-Congress excursion from September 7 to 21 will visit the main localities in Poland that contain Quaternary deposits.

INQUA was organized in 1928, during an international geological meeting in Copenhagen, for the purpose of approaching Quaternary problems on an interdisciplinary level, particularly in the fields of Geology, Archaeology, Climatology, and Chronology. Although the Congresses have been attended primarily by Europeans, they are of international interest, and non-Europeans are urged to attend.

It has been the desire of many Europeans and Americans to hold the Congress in the United States sometime in the future. To this end the National Academy of Sciences–National Research Council created a United States Committee on INQUA. This Committee is making plans to invite the next Congress to meet in this country during the late summer of 1965. AGU representatives on the U. S. National INQUA Committee are: Section of Hydrology—John P. Miller, Harvard University, and Herbert E. Wright, University of Minnesota; Section of Oceanography—Edwin L. Hamilton, U. S. Navy Electronics Laboratory, San Diego, California, and Bruce C. Heezen, Lamont Geological Observatory, Columbia University.

Persons interested in the 1961 Congress in Poland may obtain more detailed information by writing to Professor Rajmund Galon, Secretary General, INQUA, Geographical Institute, University, Tourn, Poland.

Personalia

• WILLIAM B. AGOCS, formerly Director of Geology and Geophysics of Aero Service Corp., has established a consulting service in Philadelphia in the field of natural resources evaluation.

• CHARLES A. ANDERSON, Chief Geologist of the United States Geological Survey, received an honorary Doctor of Science degree at the 67th commencement exercises of Pomona College,

Claremont, Calif., where he studied as an undergraduate.

• GORDON I. ATWATER, consulting geologist of New Orleans, was elected Vice President of the American Geological Institute at the annual meeting held in Denver last December.

• NEILS C. BECK, formerly Director-General of the Union of Burma Applied Research Institute, is now Assistant Director at the Armour Research Foundation, Chicago.

• NORMAN S. BENES OF WASHINGTON D. C., is a representative of the United States in cooperation programs with Argentinian and Australian governments at Byrd Station, Antarctica; he is acting as a coordinator of the activities of scientists working in six fields.

• LLOYD V. BERKNER, President of AGU, and formerly President of Associated Universities, Inc., New York, is now President of the Graduate Research Center, Dallas, Texas.

• KENNETH H. DRUMMOND, formerly Assistant Director of the Smithsonian Institution's Astrophysical Observatory, has been appointed Assistant to Chief Campus Officer Roger Revelle of The University of California, La Jolla. Mr. Drummond will be responsible for all general nonacademic departments on the La Jolla campus, which includes the School of Science and Engineering, and the Scripps Institution of Oceanography.

• BERNARD FRANK, recently at Forest Research Institute, Dehra Dun, India, is now Professor of Watershed Management at Colorado State University.

• O. W. ISRAELSEN, Professor Emeritus of the Dept. of Civil Engineering, Utah State University, recently conducted a course in the field of irrigation, at SEATO Graduate School of Engineering at Lahore, Pakistan, and also a short course at Bangkok, Thailand.

• GEORGE R. JENKINS, Associate Professor of Geology at Lehigh University, has been appointed Director of the Lehigh University Institute of Research.

• ROBERT W. KNECHT, Chief of the Section on Sun-Earth Relationships, National Bureau of Standards, Boulder Colorado, has been appointed Assistant Division Chief of the Ionosphere Research and Propagation Division.

• DALE C. KRAUSE, Oceanographer at the Scripps Institution at La Jolla, California, has received a National Science Foundation Postdoctoral Fellowship; he will study at the New Zealand Oceanographic Institute.

• KONRAD KRAUSKOPF, Associate Dean of the School of Mineral Sciences of Stanford University, was awarded the Arthur L. Day Gold Medal of the Geological Society of America, for his research on the characteristics of ore-forming solutions.

• GORDON G. LILL, Formerly of the Geophysics Branch, Office of Naval Research, is now with the Lockheed Aircraft Corporation, Burbank, California, as Senior Scientific Advisor in the Corporate Development Planning Division.

• JOHN B. LUCKE, Professor of Geology at the University of Connecticut, Storrs, Conn., has resigned as Director of the Connecticut Geological and Natural History Survey, a post he has held since 1956.

• MAX C. MCLEAN, since 1945 Oceanographer at the U. S. Navy Oceanographic Office, is now Scientific Liaison Officer for the Office of Naval Research, and is stationed at the Woods Hole Oceanographic Institution.

• JOE WEBB PEOPLES, Chairman of the Department of Geology at Wesleyan University, Middletown, Conn., has been appointed Director of the Connecticut Geological and Natural History Survey.

• WALTER RUSKA, formerly President of Ruska Instrument Corporation, has resigned as President of this corporation and has established offices as a consultant in various phases of instrumentation. He will be closely associated with the Electro-Mechanics Company of Austin, Texas.

• FRED C. SCOBEY, consulting hydraulic engineer at Berkeley, Calif., has been made an Honorary Member of the American Society of Civil Engineers.

• EDWARD S. C. SMITH, for 35 years Professor of Geology and Chairman of the Department of Geology at Union College, Schenectady, N. Y., has retired; alumni and friends of the Department have established a prize fund in Geology in his honor.

• PIERRE ST. ARMAND has returned from the University of Chile to the U. S. Naval Ordnance Station, China Lake, California.

• EARLE F. TAYLOR, consulting engineer of Houston Texas, has announced the formation of a consulting firm in petroleum exploration and development, known as Taylor and Associates, Inc.

• RICHARD TOUSEY, head of the Rocket Spectroscopy Branch, Atmospheric and Astrophysics Division, U. S. Naval Laboratory, has received the Optical Society's *Frederic Ives Medal* for 1960. The Medal is awarded every two years for distinguished research in optics.

• GORDON R. WILLIAMS, recently Professor of Hydraulic Engineering at Massachusetts Institute of Technology, has rejoined the New York firm of Tippetts, Abbet, McCarthy and Stratton.

• DONALD MCCORD BAKER, Consulting Geologist of Los Angeles, California, died on October 1, 1960. He was born in Poway, San Diego County, California, November 25, 1890. He studied Civil Engineering at the University of Southern California, and at the University of California at Berkeley, where he graduated with the degree of Civil Engineer. From 1911 until 1917 he was an engineer with the U. S. Indian Irrigation Service. From 1917 to 1924 he practiced as a consulting engineer, and in 1942 became a partner in the firm of Ruscardon Engineers. He again went into business for himself in 1954. At various times he served as consulting engineer to the Los Angeles Flood Control District, the Long Beach Water Department, the Colorado River Board of California, the Water Resources Committee of the National Resources Planning Board, and others. His field of activity was varied,

including general hydrology resources studies, irrigation problems, traffic engineering, and engineering economics. He received the Certificate of Merit from the Urban Land Institute, and a citation from the Sultan of Morocco with a medal that made him an officer of the Order of Ouissam Alaouite—the Sultan's personal order. He contributed numerous articles to the technical journals, and a section on behavior of ground water in the Hydrology Handbook of the American Society of Civil Engineers. Also he was co-author of a book 'Water Supply and Utilization'. He was a member of the American Society of Civil Engineers, the American Water Works Association, the International Commission on Irrigation and Drainage, and the American Academy of Political and Social Science, and a Fellow of the American Geographical Society. He joined the AGU in 1931.

● HELLMUT BERG of the Meteorological Institute of the University of Cologne, Germany, died on March 2, 1960. He was born in Baden, Germany, November 2, 1908. He took his Doctorate at Heidelberg University in 1931. He had been Professor of Meteorology and Geophysics at the University since 1945, and was widely known for his work and publications in these fields. He became a member of AGU in 1957.

● CALDER TUPPER BRESSLER died in September 1959, while doing geologic work on Mt. Rainier. He was born in Minneapolis, Minn., on August 26, 1919. He graduated from the University of Washington in 1942, with the degree of Bachelor of Science in Geology, and obtained a Ph.D. degree in Mineralogy from Pennsylvania State College in 1951, where he had been a graduate teaching assistant since 1946. He was assistant Professor of Geology at the University of Idaho, 1951–52, and at the University of Orgeon, 1952–1957. At the time of his death he was Professor in the Department of Science, Western Washington College of Education. He was on the staff of the U. S. Geological Survey, Alaskan Branch, from 1942 to 1946. His principal work and interests, besides teaching, were in the fields of petrography, petrology and mineral resources of the Pacific Northwest, and mineral deposits of Alaska. He became a member of AGU in 1946.

● PETER CHRZANOWSKI of the National Bureau of Standards died on April 11, 1960, at his home in Chevy Chase, Maryland. He was born in New Britain, Conn., June 3, 1910. He went to the Bureau in 1929 where, until 1941, he assisted in a redetermination of the constant of gravitation. Meanwhile, he studied at George Washington University, where he received the B.S. degree in Physics, in 1937. From 1951 until his death he was the leader of the Bureau's Infrasonics group, with which he worked in the development of a new method of detecting earthquakes and tornadoes. He received the Meritorious Service Award of the Department of Commerce in 1952 for major scientific contributions to the design and construction of instruments for measuring sound at infrasonic frequencies. He became a member of AGU in March 1960.

● WARD FOLLETT DAVIDSON, of Port Washington, N. Y., died on July 12, 1960. He was born in Commonwealth, Wisconsin, October 21, 1890. He graduated from the University of Michigan in 1913 with the degree of B.S. in Electrical Engineering, and obtained an M.S. at that institution in 1920. He was employed as an engineer with the Westinghouse Electric and Mfg. Co. from 1914 to 1916. He returned to the University of Michigan in 1916 as instructor in electrical engineering, and became Assistant Professor in 1922. He became Director of Research for the Brooklyn Edison Co. in 1922, and for the Consolidated Edison Co., of New York in 1937. He retired in 1955. From 1927 to 1939 he was Secretary of the Conference on Electrical Insulation, National Research Council, and Chairman from 1939 to 1948. He was a Captain in the U. S. Army, Corps of Engineers, 1917–1919. His principal interests and work were in the fields of high-voltage cables, electrical insulating materials, nuclear power generation, mutual interaction of electric power and communication systems, and atmospheric pollution. He had been a member of AGU since 1948.

● ERLE LEROY HARDY, Regional Director of the U. S. Weather Bureau at Fort Worth, Texas, died on June 22, 1960. He was born in Yankton, South Dakota, August 31, 1894. He studied at New Mexico Agricultural College, now the University of New Mexico. In 1912 he entered the U.S. Weather Bureau as an observer. During World War I he served in France with an artillery soundwave detection unit. After the War he continued his services with that Bureau, involving snowfall, run-off, and erosion studies, and later, rainfall and evaporation studies in connection with a survey made for the National Resources Committee relating to the distribution of waters of the Pecos River. He acted in an advisory capacity for similar studies of the Rio Grande Basin. From 1938–1941 he supervised a hydrologic program for the Weather Bureau at Albuquerque. In 1941 he went to Fort Worth as Director of the local regional office of that Bureau. He made important contributions to the science of weather reporting, which led to an integrated storm warning system, a radar network for reporting tornadoes, and a national hurricane preparedness plan. He was awarded both the Gold and Silver medals of the Department of Commerce, for Meritorious Service. In 1959 he received a plaque from the Fort Worth Chamber of Commerce for his public services. He was a charter member of the American Meteorological Society, and a member of AGU since 1945.

● BELA HUBBARD, Consulting Geologist, of Tucson, Arizona, died on November 4, 1959. He was born in Detroit, Michigan, on August 10, 1890. He studied Geology at Columbia University, where he received the degrees of B.S., 1914; M.A., 1916; and Ph.D., 1922. He taught at that University from 1915 to 1917, and at Queens Univ., Canada, 1917 to 1920. He became field geologist for Carter Oil Co., in 1920, was a party chief for Standard Oil Co. of New Jersey 1920–1922, and Chief Geologist for Standard Oil Co., of Venezuela from 1922 to 1927. From 1927 to 1930 he was chief geophysicist for the Creole

Petroleum Corp. In 1935 he returned to the Standard Oil Co., of New Jersey, as assistant to the Chief Geologist, becoming staff geologist in 1945. He began private consulting work in 1950. He was a Fellow of the Geological Society of America, the Paleontological Society, and the American Geographical Society. He had been a member of AGU since 1934.

● MARTIN R. HUBERTY, Director of the Water Resources Center, and Acting Dean of the College of Agriculture, University of California at Los Angeles, died on December 12, 1960. He was born in Calaveras County. He graduated from the University of California in 1920, with the degree of Bachelor of Science in irrigation engineering, following his return from war service abroad with the 372nd Aero Squadron. He was associated with the University of California continuously from 1921 until his death, except during a period of leave in 1933–34 when he went to Stanford University to obtain a professional degree of Engineer.

Dean Huberty achieved world fame for his many research accomplishments, particularly in the field of soils sciences. He was senior editor and principal contributor to a book, 'Natural Resources' published in 1959; he contributed also to other books relating to the fields of water resources and irrigation. In 1951–52 he went to Rome on leave of absence, as Senior Irrigation and Drainage Officer for the Food and Agricultural Organization of the United Nations, and in this capacity made special studies in several countries of the Near and Middle East, and India.

He was a member of the ASCE, the ASAE, the Soil Science Society of America, and had been a member of AGU since 1935.

● SIR HAROLD SPENCER JONES, London, England, died on November 4, 1960, at the age of 70. He was Astronomer Royal from 1933 to 1955, and Secretary-General of the International Council of Scientific Unions since 1956. He was a former President of the British Astronomical Association, the British Horological Institute, and the International Astronomical Union. He received many foreign honors, among them the 1955 medal of the Rittenhouse Astronomical Society of Philadelphia. Among his many writings are the books *A Picture of the Universe* (1947), and *Worlds Without End* (1935).

● JOHN T. LONSDALE, Director of the Bureau of Economic Geology, University of Texas, since 1945, died on October 5, 1960. He was born in Dale, Iowa, November 8, 1895. He received an A.B. degree in 1917 and an M.S. in geology in 1921, both at the University of Iowa. In 1924 he was granted a Ph.D. in geology by the University of Virginia, where he had been teaching since 1921. In 1924–25 he was Assistant Professor of Geology at the University of Oklahoma. He went to the Bureau of Economic Geology as geologist in 1925. He was head of the Department of Geology at Texas A. and M. College from 1928 to 1935, and at Iowa State College from 1935 to 1945. He returned to the Bureau of Economic Geology at the Univ. of Texas in 1945, as Director, and Professor of Geology. He was author of numerous scientific reports and papers on mineralogy, petrology, mineral resources, and ground water geology, mainly of Texas areas. He served as a first lieutenant in the U. S. Army, 1917–1919, and lieutenant-colonel and colonel of the General Staff Corps, 1942–1945. He was a Fellow of the Geological Society of America, and a member of the Mineralogical Society of America, the Society of Economic Geologists, the American Institute of Mining and Metallurgical Engineers, the American Association for the Advancement of Science, and the AGU (since 1934).

● JOHAN VAN VEEN, retired Chief Engineer and Director of the Rijkswaterstaat, s-Gravenhage, The Netherlands, died on December 10, 1959. He was born on December 21, 1893 at Uithuizermeeden, a village in the Dutch province of Gröningen. After completing his education at the Technological University, Delft, in 1919, he accepted an appointment as engineer at a provincial Public Works Service. From 1926 to 1928 he was employed in Surinam by the American Bauxite Company. He joined the Rijkswaterstaat in 1929. His subsequent studies on currents, sand movement, and salinity in the tidal rivers and estuaries contributed greatly to solution of the problems of intrusion of saline waters, and safety against inundations, and his advice and wide knowledge in these fields brought him deserved fame at home and abroad. He had been a member of AGU since 1949.

● GEORGE WINCHESTER, retired, formerly Professor of Physics at Rutgers University, died on February 14, 1960. He was born in Elmore, Illinois, on May 22, 1874. He obtained a doctorate from the University of Chicago in 1907. He was Professor of Physics at University of Washington, 1906–1907, and head of the Dept. of Physics at Washington and Jefferson College, 1907–1919. From 1921–1946 he was on the faculty of Rutgers University and became Professor Emeritus in 1946. In 1950 he was called to Pennsylvania State Teachers College, at Edinboro, to establish a teacher's training course in physics. Besides teaching, his fields of particular interest included photoelectricity, radioactivity, low temperatures, and solar radiation. He was a member of AGU since 1930, and a life member since 1946.

Union, Section, and Committee Activities

Minutes of Executive Committee Meeting, American Geophysical Union

October 22, 1960

The meeting was called to order at 09h 30m in the Reading Room of the National Academy of Sciences, 2101 Constitution Avenue, Washington, D. C., by President Lloyd V. Berkner.

Present—P. H. Abelson, W. W. Atwood, L. T. Aldrich, L. R. Alldredge, James Balsley, L. V. Berkner, Walter H. Bucher, Earl G. Droessler, Edward B. Espenshade, Irving Friedman, H. Richard Gault, Linn Hoover, Floyd W. Hough, W. C. Jacobs, Robert Jastrow, J. W. Joyce, Joseph Kaplan, W. D. Lambert, H. E. Landsberg, W. B. Langbein, John Lyman, Thomas F. Malone, Leonard M. Murphy, J. Hugh Nelson, Homer E. Newell, Hugh Odishaw, James A. Peoples, Jr., D. W. Pritchard, F. W. Reichelderfer, Mrs. Ethel G. Sanders, A. Nelson Sayre, Alan Shapley, Waldo E. Smith, C. A. Whitten, and Ralph N. Wilson.

Report of the General Secretary

The report of the General Secretary for the Executive Committee meeting of April 25 and 29, 1960, was recorded in the minutes, and published in the September 1960 issue of the *Transactions* (pp. 457–462).

Approval of Minutes—The minutes of the Executive Committee Meeting of April 25 and 29, 1960 were circulated to the Committee, approved by mail ballot, and published in the *Transactions* of September 1960, pp. 457–484. The minutes of the special meeting of the Executive Committee held in Helsinki on July 27, 1960 have also been circulated to the Executive Committee, approved by mail ballot, and published in the *Transactions* of December 1960, pp. 681–682.

Changes in Executive Committee—Since its April meeting some changes have been made in the Executive Committee, largely because of elections of members to offices of the International Union of Geodesy and Geophysics. Perry Byerly was elected President of the International Association of Seismology and Physics of the Earth's Interior; he has already been on our Executive Committee to June 30, 1960, as Chairman of the Section of Geophysics of the National Academy of Sciences. Others, who were already officers of IUGG Associations, were advanced as follows: Horace R. Byers from Vice President to President of the Association of Meteorology and Atmospheric Physics, Charles A. Whitten from Vice President to President of the Association of Geodesy, and Joseph Kaplan from President of the Association of Geomagnetism and Aeronomy to become one of the two Vice Presidents of the Union. J. F. Schairer is no longer Vice President of the Association of Volcanology, but he remains on our Executive Committee as the retiring President of our Section of Volcanology, Geochemistry, and Petrology. Gordon A. Macdonald has been elected Vice President of the International Association of Volcanology. On the other hand, we have lost from our Executive Committee P. H. Abelson, who resigned as Chairman of our Committee on Meetings has been replaced by L. T. Aldrich. L. B. Slichter has taken Perry Byerly's place as Chairman of the Section of Geophysics of the National Academy of Sciences. Robert C. Elderfield has replaced E. H. Volwiler as Chairman of the Division of Chemistry and Chemical Technology of the NAS–NRC, and Edward B. Espenshade, Jr. has replaced John H. Adkins as Chairman of the Division of Earth Sciences of the NAS–NRC.

Actions of Executive Committee by mail ballot—Since the last meeting of the Executive Committee, the following actions have been taken by mail ballot:

Date	Subject	Approve	Disapprove
1960			
May 5	Proposed corporation member: Cooper Development	40	0
May 6	Second list of proposed new members	39	0
May 17	Proposed corporation member: Lockheed Aircraft Corporation, California Division	36	0
June 20	Minutes of the Executive Committee Meeting of April 25 and 29	26	0
June 22	Changes in Statutes and By Laws	37	0
June 23	Third list of proposed new members	36	0
July 20	Fourth list of proposed new members	32	0
Aug. 29	Proposed corporation		

Continued

Date	Subject	Approve	Disapprove
1960	member: Grumman Aircraft Engineering Corporation	37	0
Sep. 16	Proposed corporation member: Rand Corporation	29	0
Sep. 27	Fifth list of proposed new members	27	0
Sep. 28	Minutes of the Executive Committee Meeting of July 27	24	0

Publications—The *Journal of Geophysical Research* has gone forward each month. The October issue, almost 500 pages, should be released about the time of our meeting on October 22, and the November issue is well advanced. Both of these numbers are large, and the increase in size of the *Journal* has been one of the factors that have led to the thought that possibly the *JGR* should be issued semimonthly, making a division in subject matter in some way. If the number of pages can be geared appropriately to income through page charges and reprint charges, our financial situation with regard to increasing the numbers of pages does not tend to be as critical as it might be otherwise. On the other hand, such charges tend to militate against increasing the foreign contributions to the *JGR*, and as we are anxious to include many of these the proposition is to be laid before you to consider a request for a grant from the National Science Foundation to cover charges to foreign authors.

A summary of the issues of *JGR* from May through September 1960, and of the *Transactions* for June and September 1960 is shown in the following table.

Issue	Text pages	Unumbered pages	Pages of paid advertising	Edition
Journal of Geophysical Research				
May 1960	314	14	8	9770
June 1960	220	4	3½	9530
July 1960	348	12	6	9504
Aug. 1960	350	10	6	9558
Sept. 1960	462	18	11	9500
Transactions				
June 1960	284	12	2½	9229
Sept. 1960	134	10	2	9200

The *Transactions* have been issued quarterly. The June 1960 number contained the 192-page Triennial Report to the 12th General Assembly of IUGG for which we received an original grant of $5000.00 to meet the increased size and number, and, since, the meeting of the Executive Committee in April, a supplemental grant of $4400.00 from the National Science Foundation. Fourteen hundred of these reports were sent to Helsinki for distribution to delegates. The report was received very well. We made arrangements with the Office of Information of the Department of State to ship these to Helsinki; in exchange, we supplied them with 1000 copies, which they plan to place in colleges, universities, and various libraries throughout the world.

It is anticipated that the December issue of the *Transactions* will contain a rather extensive report on the meetings at Helsinki of the Union and the seven Associations, so as to inform American scientists of both the administrative and the scientific developments. To aid us financially in this the Executive Committee is now asked to approve an application to the National Science Foundation for a grant.

Arrangements have been made by the Geophysical Research Board and the Space Board of the National Academy to continue the *IGY Bulletin*, including its publications in the *Transactions*.

Translation and publication of the English edition of *Izvestiya* of the Academy of Sciences USSR, *Geophysics Series* for 1959, was completed in midsummer. A grant of $57,730 has been approved by the National Science Foundation for continuing the series through 1960 ($20,000 of this has already been received). No. 1 of 1960 has been completed and distributed. The translation of No. 2 has been completed and turned over to the compositor, and others are in an advanced stage of translation. Our schedule contemplates that we will get as nearly caught up as possible in this endeavor during the balance of the present calendar year, and that thereafter the issues of the English edition will follow the publication of the Russian edition by only five or six months, so that the 1960 series should be complete by May 1961. Dr. Jardetsky is doing an outstanding job as our translation editor, in organizing the panel for this work and taking care to see that the translations are of top-notch quality. Composition and printing are being done by McGregor and Werner, Inc.

Izvestiya for 1957 has been completed, and financial settlement with the Pergamon Press has been made.

Nos. 37, 38, 39, and 40 of *Trudy* of the Geophysical Institute of Moscow have been completed; the first three have been released and the fourth should be released shortly. The production and distribution of this is directly in the hands of Consultants Bureau, with the aid of our translation consultants. No report has been received concerning the sales of these. Copies of the first three were on display in Helsinki, and received general approval.

We have instituted the production of the English edition of *Geodesy and Cartography*, in accordance with the approval of the Executive Committee last

spring, and have received a grant of $25,466 from the National Science Foundation for producing the 1959 numbers. We are negotiating with the Aero Chart and Information Center of the Air Force in St. Louis for added support of this project in order to supplement the NSF grant funds. This work has been started under agreement with Royer and Rogers, Inc. The translations of Nos. 1 and 2 are complete, have been checked by our translation consultants, and are now in the process of publication.

Plans for translating *Meteorology and Hydrology* are still in abeyance. This proposed project has been recommended by our Section of Hydrology, but some persons in the Section of Meteorology discourage it, noting that the American Meteorological Society is making selected translations of what are deemed by the meteorologists to be pertinent articles. These translations do not seem to be well distributed, a fact that points up the weakness of selected translations as compared with cover-to-cover translation of the issues.

The Russian Translation Board held a brief meeting at the time of our annual meeting last spring; this will be reported in due course by that Board.

Geophysical Monograph No. 5, based on the Second Woods Hole Conference on Cloud Physics was completed in early May, and has been distributed to purchasers. Our total edition was 1300 copies, and our present inventory is 568. The funds received for the conference and for the publication of the Monograph, plus the sales to date, do not quite balance the cost, but in a few months we should sell enough additional copies to break even.

Analysis of the earlier accounts indicates that Monographs 1 and 2, which were undertaken without grants, have paid for themselves with a favorable margin of about $4500 (No. 1, $3050; No. 2, $1450). Perhaps this should be earmarked as a fund to help support the undertaking, or, at least to start additional monographs. The Geophysical Monograph Board should take this under consideration.

Membership—Membership data as of September 28, 1960, are:

Membership as of April 12, 1960..	6219	
Reactivated	6	
New members processed May 6 to September 28, 1960 (139 regular members, 40 student members)	179	6404
Resigned	43	
Inactive	3	
Dropped (includes 125 student members)	224	
Deceased (reported since April 12, 1960); actually 17 less adjustments for 1 repetition	16	286
Total September 28, 1960		6118

Of these, 343 are student members and 100 are life members. In addition, we have 43 corporation members.

Dues unpaid—As of September 23, 1960, the following dues were unpaid:

For 1960	330
For part of 1960	9
For 1959 and 1960	138
For part of 1959	4

The 115 persons reported as not having paid their 1958 dues were approached regarding continuance of their membership; of these, 94 have finally been dropped.

Deaths—The following 17 deaths have been reported to the office since our meeting of April 25, 1960: James M. Howe, May 8, 1959; Clifton T. Barker, June 8, 1959; Frank H. Watson, Jr., July 4, 1959; Calder T. Bressler, September, 1959 (exact date unknown); George E. Winchester, February 15, 1960; Hellmut Berg, March 2, 1960; Ernest F. Carmichael, March 19, 1960; Charles T. Leeds, March 20, 1960; Peter Chrzanowski, April 11, 1960; Paul Bartsch, April 24, 1960; Howard T. Orville, May 24, 1960; Walter N. White, May 28, 1960; Joseph W. Brookhart, May 29, 1960; Martin J. Pollack, June 5, 1960; Erle L. Hardy, June 22, 1960; Ward F. Davidson, July 12, 1960; Harold L. Alling, July 27, 1960.

Finances—In accordance with the action of the Executive Committee, Garland C. Owens has been retained as consulting accountant to modernize AGU's bookkeeping system. Good progress has been made, and as of July 1, 1960, the accounts have been recast on the basis of Professor Owens' recommendations, and on the accrual rather than the cash basis. Financial reports as of June 30, 1960, have been prepared on both the old and new bases. A financial report for the first two months of the current fiscal year is also available, and a new budget based on these experiences, and on the new system of books, has been prepared in the office of AGU, but has not yet been considered by the Budget Committee.

Out assets in all accounts as of September 20, 1960, not counting outstanding bills receivable, are as follows:

Riggs National Bank, checking account	$15,947.43
Riggs National Bank, savings account	10,075.00
U. S. Treasury Bills, due January 15, 1961	28,497.70
U. S. Treasury Bills, due November 17, 1960	34,798.40
U. S. Treasury Notes, due May 15, 1965	50,000.00
U. S. Treasury Notes, due August 1, 1961	25,000.00
Northwestern Federal Savings & Loan Association	10,000.00

Continued

Prudential Building Association	9,788.07
Liberty Savings & Loan Association	5,242.55
Interstate Building Association	2,500.00
Enterprise Federal Savings & Loan Association	100.00
Eastern Building & Loan Association	10,000.00
Home Building & Loan Association	10,000.00
District Building & Loan Association	1,813.37
Jefferson Federal Savings & Loan Association	2,995.35
Total	$216,757.87

The budget adopted as a guide at the time of the spring meeting was published in the September 1960 issue of the *Transactions* (pp. 472–473). It was recognized that the new bookkeeping system would require some drastic changes in budgeting procedures.

The negotiable U. S. Treasury Notes and Bills that are the property of AGU are in the safe deposit box of the Riggs National Bank, Dupont Circle Branch.

During 1955 to 1957 five orders were filled for which payment has not yet been received. These are as follows:

Oct. 6, 1955—La Librairie Nouvelle, Geneva, Switzerland, back *Transactions*	$24.00
Jan. 26, 1956—Kisho Co., Osaka, Japan, $37.00 order for back *Transactions*	6.00
Oct. 11, 1956—Akademische Buchhandlung, Darmstadt, Germany, Geophysical Monograph No. 1	6.00
Jan. 11, 1957—Dr. C. Srinivasan, Madras 17, India, photostat copy of article in back *Transactions*	5.75
May 10, 1957—Library Magazine Service New York, N. Y., back *Transactions*	4.50
	$46.25

The General Secretary recommends that inasmuch as extensive efforts have been made to collect these without success, they should be written off as bad debts. At the same time it is noted that, in general, orders are accepted in good faith, and that most of them are paid for in the course of a few months. The items above have accumulated over a period of about five years. Nonetheless the General Secretary recommends that our future policy, except where credit has been satisfactorily established through experience or through other means, should be that orders without payment be withheld until payment is received.

Office staff—The office has been reorganized in accordance with the report of the Special Committee adopted at the Executive Committee meeting last spring. This report indicated the need for departmentalization of the work and general reorganization of the office. A publications unit has been established, and Louis W. Currier has been engaged as Assistant in Publications and Miss Mary Jane Miles has been employed to assist in this work. To accommodate the varying flow of work for the *JGR* and other aspects of publications, others of the staff are assigned to this work as needed for proofreading, typing, and so on. Mrs. Ethel G. Sanders, who has been a full-time member of the staff for about four years, has been designated as Office Manager, and Mrs. Mildred Hards has been employed to take care of accounts. Other full-time staff people, in addition to the Executive Secretary, include Carol C. Akers, Judith M. Seek, Martha K. Potter, and, as a student on assignment from Antioch College, Judith A. Linder. In addition, Glenda C. Olmstead, who has been a part-time and full-time employee for the last seven years, and Timothy O. Temple, a student at George Washington University, are with us on a part-time basis. In the editorial office at Lawrence, Kansas, Mrs. Rowena E. Peoples is engaged full time; she uses the part-time services of a student. Editor Abelson has arranged for Mrs. E. J. Stryker, Editor at the Carnegie Institution of Washington, and Mrs. Virginia Rapport, Editor at the Geophysical Laboratory, to spend part of their services on editing *JGR*.

At the April meeting a resolution was made and passed concerning a provision for retirement benefits for a specified category of senior staff member. Steps to implement this have not been completed, owing to the fact that, in order to be currently tax free, it must be tied in with a regular and approved retirement plan. The National Academy, under whose retirement plan we operate, has been in the process of changing from the New England Mutual blanket policy to the TIAA blanket policy. This problem is now being considered by the Academy, not only with respect to personnel of AGU, but likewise with respect to the general Academy problem.

J. J. Capello, who has been a member of the staff for almost ten years, had planned to retire at the end of January 1961, but on doctor's advice he has asked to be put on a leave-without-pay basis from October 1, 1960, to June 30, 1961, because of the NAS-NRC retirement provision. He is undertaking new work, on a part-time basis, that allows much latitude in working hours and will not be as demanding of his time as his present employment. The General Secretary will make a recommendation to the Executive Committee regarding a lump sum payment over and above Mr. Capello's accumulated annual leave.

Quarters—We are continuing to occupy the eight rooms on the third floor of the AAAS Building which, for the present, seem adequate for our requirements.

International matters—Chairman Joyce of the Committee on International Participation has prepared a report that will appear in the December 1960 issue of the *Transactions*, but here it is appropriate to state that perhaps the most important development in this field has been the 12th General Assembly held in Helsinki, Finland, July 26 to August 6, 1960, and attended by about 2000 persons, approximately 500 of whom were from the United States. A Symposium on Aeronomy was held in

Copenhagen during the week preceding the General Assembly in Helsinki. The Assembly was deemed to be an outstanding success, despite a great superabundance of papers, and a large and unanticipated late increase in number of participants for which accommodations had to be made.

The 13th General Assembly will be held in western United States in 1963. Vice President Malone has been designated by President Berkner to make recommendations concerning the time, place, and organization of this meeting. A report will be presented at the Executive Committee meeting for discussion and action.

Meetings—Our Annual Meeting is scheduled to be held in Washington, April 18–21, 1961. Program plans for some of the Sections are already well advanced and the other Sections are urged to plan their programs as rapidly as possible. Early indications are that it will be a very good meeting.

The resolutions passed at the Annual Meeting last spring have been forwarded appropriately, and several responses have been received from the recipients.

The Geophysical Society of Hawaii (the Mid-Pacific Regional Group of AGU) holds occasional meetings, usually in evenings.

The Pacific Northwest Regional Group held its annual meeting in Moscow, Idaho, on October 19 and 20, 1960. The Executive Secretary attended and will report on the meeting.

The Pacific Southwest Regional Group will hold its annual meeting at the University of California in Berkeley, on January 26 and 27, 1961.

Our Committee on Planetary Sciences is arranging a program in connection with the meeting of the American Association for the Advancement of Science, December 26–31. The AGU will also sponsor or lend moral support to other meetings, such as that of the National Science Teachers Association, at which Harry Wexler and Hugh Odishaw will speak on results of the IGY.

AGU is one of the sponsoring organizations for a symposium on scientific literature of Communist China to be held under the auspices of the AAAS, and Walter B. Langbein is serving as our representative on the *ad hoc* Committee.

Statutes and By Laws—As reported in the September 1960 issue of the *Transactions* (pp. 486–487), and as indicated by the mail ballot, several changes in the Statutes and By Laws were presented to the membership for action. The Committee of Tellers advises that the changes in the Statutes were approved. Final action should be taken at this meeting with respect to the related By Laws on which preliminary action was taken at the meetings in April, and at Helsinki in July. The changes in the Statutes still require action by the Governing Board of our parent organization; this action should be complete within the next few days, after which, the changes will be considered to be in full force and effect. We will proceed with elections during the subsequent weeks, in accordance with the changes. The ballot on the new officers will be in the hands of the membership during December.

Committee on Geophysical Data—It has been suggested that a Committee on Geophysical Data be established to survey the IGY data centers and other sources where data are available to determine whether or not these really meet the needs of researchers, and to make appropriate recommendations. This recommendation dates back, apparently, to a conference in which Woodrow Jacobs took part a year or so ago, and in which he recommended to the Air Weather Service that the services of AGU be sought in connection with these problems. The memorandum on this never reached the AGU; however, a conference on the subject was held recently at the Pentagon. This conference was attended by Jacobs, Droessler, and others, and the question (based on the earlier memorandum) was raised with respect to geophysical data, though not specifically with respect to AGU. Jacobs and Droessler have prepared a memorandum, which is in the agenda.

Miscellaneous—The Executive Secretary was invited to participate in the conference on scientific manuscripts which was held by the History of Science Society on May 5 and 6.

AGU was represented by Albert S. Fry at the inauguration on May 10 of Andrew David Holt as President of the University of Tennessee.

An invitation has been received from the National Society for the Study of Communication concerning a conference to be held in the summer of 1961 at Louisiana State College. No commitment has been made yet as to our participation or representation.

Congressional hearings on 'radiation protection criteria' and 'standards for basis and use' extended over the interval from May 24 through June 3, 1960.

Notice was received concerning a conference on the Project VELA, held in Washington on October 4 and 5, 1960. Attendance at this conference required security clearance in the secret category. Several of the participants are active members of AGU, though they did not attend as official representatives of AGU.

President Berkner addressed a letter to the Secretary of Commerce in early May endorsing the establishment of a seismological laboratory in the United States Coast and Geodetic Survey.

A. NELSON SAYRE,
General Secretary

Action on the General Secretary's report—The report was accepted.

Actions on recommendations in the General Secretary's report—With regard to the long outstanding accounts receivable, amounting to $46.25, and the related problem, a motion was made and passed that:

> These accounts be listed as uncollectable and wiped from the books, excepting that those owing be placed on a list from whom orders will be accepted only upon receipt of payment in advance, and that a list be established of those who do not pay quite promptly, likewise orders from these will be accepted only upon receipt of the payment.

With regard to J. J. Capello, who had been a member of the staff for almost ten years and who had asked to retire voluntarily in advance of his normal retirement date, it was moved and approved that:

> A payment of $546.91 be made to him to cover the total amount on his retirement plan under AGU and the National Academy of Sciences until the formal retirement date June 30, 1961, and his group insurance premium for the same interval; also, after a lapse of two years the matter should be reviewed to determine whether circumstances indicated any further payment.

President's Report

The President reviewed the principal events since the meeting in April, noting that a full report of the General Assembly held in Helsinki would be reported in the December issue of the *Transactions*. His discussion also included the activity of the CIG and its American counterpart, the Geophysics Research Board, noting that this currently involves three major projects (1) the Sunspot Minimum Program (SMP), (2) the World Magnetic Survey, and (3) the Upper Mantle Program, of which the Seismic Improvement Program may be considered an essential part. He noted that the officers were pleased with the reorganization of the Secretariat of the AGU, and felt that the annotated agenda circulated two weeks in advance, insofar as it was complete, is definitely helpful in coming to grips with AGU problems. He expressed the view that the coordination and the cooperation of the Secretariat with the various Sections and Committees could now be improved further. He noted also that the duties of the Executive Secretary includes working actively with Committees to provide assistance in planning and implementing their activities. With respect to the Membership Committee, the Secretariat bore direct responsibility for promotional activities to the end that the AGU may be fully representative of all phases of geophysical science.

The reorganization of the finance structure of the Union and the placing of the bookkeeping and accounting system on a more informative basis has proceeded very well, and it should be on a routine basis by the end of the year.

He indicated that the study of a possible West Coast National Meeting has been under way by a Committee, and that a report recommending such meetings, the first to be held in the closing days of 1961, would be offered for action later by Joseph Kaplan, Chairman.

He noted that the Thirteenth General Assembly is to be held in the United States and that Vice President Malone, AGU, in cooperation with Vice President Joseph Kaplan of the IUGG, and the Executive Secretary, had surveyed the West Coast situation, and would bring in recommendations at this meeting.

He called for the report of the Committee of Tellers (see Appendix 1), which noted that the changes in the statutes had been approved by a very large majority, and that the Governing Board of the National Academy of Sciences had likewise approved the changes. It was noted that the changes in the By Laws required a second action by the Executive Committee to put them into effect. The President interrupted his report for the motion which was made and approved that:

> The By Law amendments relating to the changes in the statutes as approved at the special meeting of the Executive Committee in Helsinki and as published in the September 1960 issue of the *Transactions*, pages 486–487, be given confirming approval.

The President expressed pleasure at the large majority and noted the institution of the new Council, which will serve as the governing board of the American Geophysical Union, replacing the Executive Committee, as set forth in the revised Statutes. A motion was made and approved that:

> Propositions 1 and 2 of the recent ballot on the Statutes and By Laws (both propositions relating to the change in the Governing Board of the AGU) be made effective January 1, 1961, and Proposition 3 (relating to the terms of the administration and the election of Officers) be made effective November 1, 1960.

The new Council, effective January 1, 1961, will then consist of the following:

- President, Lloyd V. Berkner
- Vice President, Thomas F. Malone
- General Secretary, A. Nelson Sayre
- Retiring President, Maurice Ewing
- Secretary for International Participation, J. Wallace Joyce
- President or his designated representative of each Section of the Union; the Presidents are:
  - Geodesy, Charles Pierce
  - Seismology, L. M. Murphy
  - Meteorology, Thomas F. Malone
  - Geomagnetism and Aeronomy, Leroy R. Alldredge
  - Oceanography, Walter H. Munk
  - Volcanology, Geochemistry, and Petrology, Alfred O. C. Nier
  - Hydrology, Walter B. Langbein
  - Tectonophysics, Patrick M. Hurley
- A qualified geophysical scientist nominated by each of the following four government agencies:
  - Department of Defense
  - Department of the Interior
  - Department of Commerce
  - National Science Foundation
- The Foreign Secretary of the National Academy of Sciences, H. P. Robertson
- Chairman of the Section of Geophysics of the National Academy of Sciences or a duly designated representative; the Chairman is L. B. Slichter

Chairman of the Division of Earth Sciences of the National Research Council or a duly designated representative; the Chairman is Edward B. Espenshade

Three members at large nominated by the Section of Geophysics of the National Academy of Sciences

Officers of the International Union of Geodesy and Geophysics who are citizens and residents of the United States:

Joseph Kaplan, Vice President, IUGG

K. Hilding Beij, Member, Finance Committee, IUGG

C. A. Whitten, President, W. D. Lambert, Honorary President, Association of Geodesy

Perry Byerly, President, Association of Seismology and Physics of the Earth's Interior (C. L. Pekeris is Vice President of the Association and a citizen of the United States but not currently a resident)

Horace R. Byers, President, Association of Meteorology and Atmospheric Physics

Gordon A. Macdonald, Vice President, Association of Volcanology

Harold G. Wilm, Honorary President, Association of Hydrology

Executive Secretary of the Union shall serve as Secretary of the Council with voice but without vote, Waldo E. Smith

The question was raised concerning the participation in such council meetings by persons who are active in AGU's work, such as the Editors of principal publications. The President stated that it would be the firm policy to invite principal leaders of AGU activities to attend meetings of the Council, this procedure being a continuance of the long established policy.

Reports of Committees

International Participation—Chairman Joyce noted that an extensive report on the Helsinki Meeting, including the Union's part of the meeting, will be published in the December 1960 issue of the *Transactions*. This would serve as the major part of his current report.

He noted that the revised Statutes of AGU specified that the Council should include the officers of the IUGG who are citizens of the United States and recommended that 'the officers' be interpreted to include those U. S. Citizens holding any of the following offices: the President, the Vice Presidents, the General Secretary, the Treasurer, and the Members of the Bureau of IUGG; members of the Finance Committee of the IUGG; the Honorary Presidents, the Presidents, the Vice Presidents, the Secretaries of each of the seven Associations, and no others. As no question was raised this interpretation is accepted.

He noted that from the Twelfth General Assembly the following, who are citizens and residents of the United States, would then be designated as the Officers:

International Union of Geodesy and Geophysics
Vice President, Joseph Kaplan
Finance Committee, K. Hilding Beij
Associations
Geodesy—President, Charles A. Whitten (in addition, Walter D. Lambert continues as Honorary President)
Seismology and Physics of the Earth's Interior—President, Perry Byerly
Meteorology and Atmospheric Physics—President, Horace R. Byers
Volcanology—Vice President, Gordon A. Macdonald (Hawaii)
Hydrology—Honorary President, Harold G. Wilm

Chairman Joyce noted that the new Commission on the Upper Mantle had been established in the IUGG, the work of which appears to impinge on four Sections of the AGU, namely, Seismology; Geomagnetism and Aeronomy; Volcanology, Geochemistry, and Petrology; and Tectonophysics. It was suggested that the four Presidents of these Sections form an AGU Committee on the Upper Mantle Problem. A motion was made and passed that:

> A four-section committee be appointed consisting of the Presidents or their designated representatives. The Reporter for Seismology to CIG, Frank Press, was designated *ex officio*. Leonard M. Murphy, President of the Section of Seismology was designated as Chairman.

Vice President Malone had been designated by the President as Chairman of an *ad hoc* Committee to bring in recommendations concerning the Thirteenth General Assembly of the IUGG (see Appendix 2). He noted that in company with the Vice President of the IUGG, Joseph Kaplan, and the Executive Secretary of AGU, Waldo E. Smith, he had visited Stanford University, the University of California at Berkeley, the University of California at Los Angeles, and the University of Southern California (Vice President Kaplan could not accompany to USC). He noted that there are splendid facilities at all places visited, although at the University of Southern California the meetings would, in large part, need to be in the nearby Sports Arena, and therefore away from the academic atmosphere that is particularly desired. Discussions were held in terms of a possible attendance of 3000. If the meeting should turn out to be any larger, difficulty would probably be encountered at Stanford, where few lodging facilities are available beyond those available at the University dormitories. There were definite advantages in favor of the Berkeley site, where meeting facilities included dormitory and dining accommodations that were more than adequate. The Committee recommended (Kaplan abstaining but not objecting) that Berkeley be selected as the site and that the time be approx-

imately the last week of August and the first week of September, 1963. A motion was made and approved that:

> The Thirteenth General Assembly of the IUGG be held on the University of California campus at Berkeley, and, with some latitude, during the last week of August and the first week of September, subject to adjustment in time to coordinate with the General Assembly of URSI in Japan in 1963, and with the meeting of the Inter-Union Committee on the Ionosphere.

Joseph Kaplan noted that the international organization is encouraging the holding of subject matter symposia under the auspices of the various Associations, preferably before, but possibly after, the General Assembly; these would be similar in character to the Symposium on Aeronomy that was held in Copenhagen during the week preceding the opening of the General Assembly in Helsinki. He noted that a symposium in hydrology might appropriately be held at Stanford, one in aeronomy at UCLA, and that others might be appropriately scheduled elsewhere.

With regard to organization, Malone recommended that three general committees be formed: a General Arrangements Committee (to be activated as promptly as possible), a Local Arrangements Committee (to be activated during 1961), and a Finance Committee (to be activated as promptly as possible). The Finance Committee will be concerned immediately with determining what funds must be raised, and what deadlines should be established for these. An approximate budget must be set up by January 1, 1961, with a report on sources that might be tapped by April 1. It was noted that the accounts for the general assemblies of ICSU unions are customarily established directly under the National Academy of Sciences. A motion was made and passed that:

> The *ad hoc* committee be continued, under the Chairmanship of Vice President Malone, to plan and form such permanent committees as are necessary in connection with the General Assembly to be held in 1963. The National Academy of Sciences is requested and authorized to be custodian of funds for the General Assembly.

It was noted that 1963 is likewise the centenary of the National Academy of Sciences and that certain Academy functions could be joined with the Thirteenth General Assembly. This would seem to be highly desirable and appropriate, and the suggestion will be brought to the attention of the Academy.

In order to avoid any conflict with URSI and the Inter-Union Committee on the Ionosphere, the Committee was requested to get into touch with I. Koga and W. J. G. Beynon.

Regarding the Thirteenth General Assembly, W. W. Atwood of the Office of International Relations pointed out that his office, as well as the entire Academy staff, would be ready to work very closely with the General Arrangements Committee, and that there are many ways in which the Academy can be helpful, especially with regard to problems that must be worked out with the Department of State.

Concerning the increase of dues to the IUGG, Atwood noted that it is extremely important for the Executive Committee to present a strong case to the Governing Board of the Academy in support of the substantial increase in the United States contribution. The Academy, as the adhering body, will have the responsibility of paying the dues for the Union. In the past we have had support from the Department of State for the payment of most of these dues. It is possible that, under some conditions, the State Department would not pay the dues (for instance, if Red China adheres).

The AGU Secretary for International Participation agreed to preface the necessary supporting case for presentation to the Academy through the Office on International Relations.

Hugh Odishaw reported that the President of the Academy is now engaged in establishing the Geophysics Research Board as the U. S. National Committee of CIG. This Committee will have ten or eleven members, four of whom have been recommended by the U. S. National Committees concerned with the IUGG, IAU, URSI, and IUPAP. In addition, Chairmen of certain Academy Committees (the Space Science Board, the Committee on Polar Research, the Committee on Oceanography, the Committee on Atmospheric Sciences, and the U. S. National Committee for IGY) will be members, and one or two others may also be designated by the President of the Academy.

CIG has two primary areas of interest: (1) activities in termination of the IGY and carried forward by the CIG, and (2) international cooperative geophysical programs in the future, involving more than one International Union. Regarding (1) the CIG is pursuing completion of data interchange and of the *Annals*. Regarding (2) the CIG is organizing the continued interchange of geophysical data, as recommended by specialists in each field throughout the World, and is conducting several special programs, as, for example, (a) a major program on solar and terrestrial relations during the sunspot minimum, (1964–65), (b) a coordinated study of the upper mantle and the crust, and (c) the World Magnetic Survey. The CIG works closely with other special ICSU committees, such as SCOR, SCAR, and COSPAR.

Chairman Espenshade of the Division of Earth Sciences noted a desire to keep the Board small and effective. The Geophysics Research Board will function closely with the Division of Earth Sciences, and a special secretariat will be established as a continuance of the Academy-IGY activities.

The question was raised as to whether or not the Geophysics Research Board would undertake studies toward the advancement of geophysical education. It was the consensus that this should be undertaken directly by the Academy, through a special committee to be organized for this purpose. After a

lengthy discussion that stressed the importance of such a study, a motion was made and passed that:

> The Officers of AGU be instructed to work with the Division of Earth Sciences to ascertain the best basis on which a Committee on Geophysical Education might be set up, to encourage establishment of such a committee by the National Academy of Sciences to study the special problems of education in geophysics, and to prepare a report that could guide university administrations and faculties in organization of their programs of education in geophysics.

Publications—Editor Abelson served as Chairman of an *ad hoc* Committee on the Problems and the Future of JGR, and presented the report set forth in Appendix 3. He noted that there are no immediate plans to split the *Journal* into two series, but that, rather, there is a plan to publish papers bearing on hydrology and oceanography in alternate months, in order that such papers may be somewhat more concentrated for potential users. Also, a questionnaire is to be discussed, and possibly sent out to those in hydrology and oceanography, to ascertain whether or not it may be worthwhile to assemble the material relating to these subjects into a single volume of reprints at the end of each year. Sources of financial support for this will be investigated. Abelson pointed out that the contents of each issue of the *Journal* are now stratified, starting with the outermost aspects at the top and proceeding down to the center of the Earth. Therefore, a user should not find it too difficult to find the subject matter with which he is particularly concerned, even though no formal classification is given. It is very difficult to make a formal classification. A motion was made and passed to:

> Accept the report and continue the committee to make further studies.

Editor Abelson proceeded to discuss the contents of *JGR* and offered the material set forth as Appendix 4, which illustrates the contents by classification. He pointed out the desirability of securing as many high quality papers of foreign authors as is possible. This is hampered somewhat by our present policy of making the page charge. Noting that the broadest development of the *Journal* is important to adequate development of the science, it was suggested that the National Science Foundation be approached to authorize use of appropriate portions of the present grant for defraying costs of publication of foreign papers. It may be desirable—after our present grant becomes exhausted—to secure additional grant funds specifically for this purpose, so that AGU and the editors will not feel inhibited or embarrassed in soliciting distinguished papers for publication in the *Journal*. It was moved and approved that:

> The Editors and Officers explore with the National Science Foundation the possibility of using funds from the grant to AGU for JGR to defray costs of page charges for distinguished papers by foreign authors who are not able to pay such charges.

The Committee recessed for lunch at 12h 35m and reconvened at 13h 20m.

With regard to the *Transactions*, Editor Waldo E. Smith pointed out that we had received grants totaling $9400 in support of the preparation and publication of the Triennial Report to the IUGG that appeared in the June issue of the *Transactions*. Fourteen hundred copies of the report were distributed in Helsinki and 1000 more were turned over the U. S. Office of Information for distribution to libraries, universities, and educational institutions throughout the world. The total edition of the report was over 12,000. A balance of about $1800 remains from this grant.

An extensive report that will comprise 100–110 pages has been prepared on the administrative and scientific aspects of the Helsinki Meeting. It was the consensus that the report on the Helsinki Meeting should receive very wide domestic distribution. Approval was sought to request a grant from the National Science Foundation for publishing this report, taking due account of the balance already in hand. A motion was made and passed that:

> A request for a grant from the National Science Foundation be made for publication of Report of the General Assembly at Helsinki.

Director Odishaw of the IGY Secretariat confirmed the arrangements set forth in the General Secretary's Report concerning the continuation of the *IGY Bulletin*.

Chairman Shapley of the Geophysical Monograph Board noted that, because most of the members were abroad during the summer months, the Committee had been quite inactive, but that he planned to call the Committee together during the next few months in an effort to formulate a vigorous program.

The General Secretary recommended that the favorable balances shown in the accounts for Monographs Nos. 1 and 2 be set up as a fund for the Geophysical Monograph Series. A motion was made and passed that:

> The balances available from the publication of Monographs No. 1 and 2 be established as a revolving fund to aid in publishing the Geophysical Monograph series.

The Russian Translation Board presented the report set forth in Appendix 5. It was pointed out further that there has been considerable discussion, in recent months, on undertaking translations in oceanography, that a Committee under the Chairmanship of Warren Wooster had made certain recommendations involving the AGU, and that the Committee on Oceanography of the National Academy of Sciences, under the Chairmanship of Harrison Brown, had recently endorsed the plans to

undertake such work. A motion was made and passed that:

> The Russian Translation Board should make a study with regard to the translation of oceanographic material, and make a recommendation from their findings.

In connection with the oceanographic problem, it was noted that the suggestions of the Wooster Committee included the translation of the Russian Abstracts in Geophysics and that AGU had tried this and found this solution unsatisfactory. The President noted that John Lyman had found it necessary to resign as Chairman of the Committee on Abstracts and that, pending the appointment of a successor, he had been invited to the Executive Committee meeting.

It was noted that *Meteorological Abstracts* of the American Meteorological Society have been broadened under the title of *Meteorological and Geoastrophysical Abstracts* following recommendation of the AGU to cover the fluid phases of the Earth, including oceanography and outer space. Therefore this aspect of geophysics is now being adequately covered by abstracts. The American Geological Institute has a project on the lithosphere which they restrict to North America and thus do not meet the greatest need for abstracts in this field.

It was pointed out that *Geophysics Abstracts* of the U. S. Geological Survey has broadened its scope considerably in the last two years and now covers more than 200 journals from all over the World, which thus approaches our need for an abstract journal on the lithosphere. Recent discussions with those responsible indicate that they may be willing to broaden the scope of *Geophysics Abstracts* to include the phases of geodesy, oceanography, geochemistry, and hydrology not now covered, either in that journal or in the abstract journal of the American Meteorological Society. If the scope can be thus broadened, our needs for complete abstract coverage in geophysics will be obtained. With agreement of the Executive Committee,

> James Balsley, Edward B. Espenshade, and Waldo E. Smith were named as a committee to pursue this problem under the Chairmanship of Balsley it being agreed that in Espenshade's absence Linn Hoover of the Division of Earth Sciences would act.

Budget—Chairman John Reed was unable to attend the meeting, but he communicated by telephone, and expressed the thought that the proposed budget under the new accounting system (see Appendix 6) would need considerable study. He felt that this revised budget should be accepted in principle, and said that further studies would be made by the Budget Committee.

The President stated that the proposed budget had been studied by the officers and appeared satisfactory with the two certain additions, (1) there should be an increase of about $1000 in the salaries budget of the *JGR* (Schedule 2) to take care of an increase for Mrs. Peoples, whose work has increased greatly with growth of *JGR*, and for assistance that she needs in her office in Lawrence, Kansas, and (2) a further adjustment in Schedule B, the administration account, to provide an additional $2000 for travel of the Executive Secretary in support of committee activities, especially promotional efforts for the Committee on Membership. A motion was made and passed that:

> The budget set up in the agenda (see Appendix 6) with modifications recommended by the officers be accepted as a guide pending the further study by the Budget Committee.

The *ad hoc* Committee on Dues, Earl Droessler, Chairman, offered a report (see Appendix 7) at the meeting in April that was laid on the table pending assessment of AGU's financial status under the new system of cost accounting. This provides for an increase in dues from $10.00 per year to $13.00 per year. The *ad hoc* Committee had discussed this matter further and now repeated its recommendations unanimously as applying to the calendar year 1962. During the past few years, AGU has increased its services to its members greatly and has initiated many activities to advance opportunities in the science. Its volume of publication has increased greatly. Careful accounting shows that its margins are much too close for safety and stability. Moreover, the Union is operating more inexpensively than any similar organization, and no economies can be made without curtailing essential services in the advancement of geophysics. The increase in dues reflects, substantially, the inflationary factor. The increases in services have come through steadily improved management, through government assistance in support of the advancement of geophysics, and through large contributory services—without cost to the Union—by dedicated members. When costs of operation pass certain limits, new members cost the Union more than they contribute. After discussion, it was moved and unanimously passed that:

> The report be adopted, including the increase in dues to $13.00, to be effective in 1962, and that appropriate adjustments be made in the subscription rate for The *Journal of Geophysical Research* and the *Transactions*.

Our Consulting Accountant has noted that our membership year and our subscription year correspond to the calendar year, whereas our fiscal year for budget and audit purposes corresponds to the fiscal year of our parent body, namely, July 1 to June 30, and that this leads to considerable unnecessary fiscal confusion. He recommended that the calendar year be used for all purposes. Informal discussion with the Business Office of the National Academy of Sciences indicated no objection on their part. A motion was made and passed that:

> The fiscal year of the American Geophysical Union be made to coincide with the calendar year, beginning, if possible, on January 1, 1961.

Audit—A. G. McNish, Chairman. Two reports for the calendar year ending June 30 have been prepared, one on the previous cash basis, as in former years, and one on the accrual basis (see Appendix 8) in order to be able to start the new bookkeeping system as of July 1, 1960. These accounts have been gone over carefully by the Consulting Accountant who made the recommendation set forth in Appendix 9. In the light of these facts, a motion was made and passed that:

> The Audit Committee forgo its usual review of the accounts and the books, simply making a review of the funds and securities in the bank and in the accounts as of June 30, 1960 to confirm the amounts reported.

With regard to the recommended CPA audit, it was agreed, with the recommendation of our Consulting Accountant that

> Beginning with the fiscal year July 1, 1960, a full dress CPA audit be made by a qualified public accountant and reported to the Audit Committee and the Council.

Meetings—Noting that plans are now being made for an annual Western National Meeting, Chairman Aldrich suggested that his committee be designated as the 'Meetings Committee for the Annual Meeting at Washington.' He raised the question about the desire for sessions sponsored by the Union and the feeling was expressed that steps should be taken to encourage and extend Union sessions and joint sessions among Sections. The Chairman was requested to address letters to the Sections, encouraging cooperation in arranging programs on intersection themes to a larger extent. It was noted that steps have been taken already for the Section of Geomagnetism and Aeronomy to arrange joint sessions with the Planning Committee on Planetary Sciences, and it was felt that the projected program on the mantle and crust, involving the Moho plans, might likewise be developed on an inter-section basis. Homer Newell, Chairman of the Planetary Sciences Committee, pointed out that where themes encompassed more than the usual field of AGU, the development of some sessions on an inter-society basis may be desirable. Steps are being taken to develop some joint sessions with URSI.

Joseph Kaplan, Chairman of a special Committee on a Western National Meeting, made the recommendations set forth in his report (see Appendix 10), on a meeting of the Committee held in Helsinki on August 1, 1960 to the effect that a Western Meeting be held about the same time the Physical Society meets in California, that is, between Christmas and New Year's of 1961. A motion was made and approved to:

> Authorize the Western National Meeting according to the general plan outlined in Kaplan's report.

Kaplan noted further that the Pacific Southwest Regional Meeting in January 1961 would include a half-day session each on aeronomy and planetary sciences. This represents a transition to the Western National Meeting in 1961, and should be a strong drawing card for this meeting.

Executive Secretary Waldo E. Smith attended the Pacific Northwest Regional Meeting on October 19–20, reporting that this was deemed to be successful. About 100 persons attended. Seventeen papers were given. Non-technical talks were given at an evening banquet, and a talk about AGU matters by the Executive Secretary at the luncheon meeting. Two or three of the papers presented may make good contributions to the *Journal of Geophysical Research*, but most of the papers were either on the order of progress reports, or the outlining of plans, or the development of instruments, and might appropriately be subjects of one-or two-page letters in the *JGR*. Vice President William C. Ackermann of the Section of Hydrology presented a paper on the needs in hydrology that seems to fit appropriately into the *Transactions*. Most of those who attended were in the field of hydrology, and were more concerned with applications rather than with basic research. Regional meetings seem to meet a real need of the area. The Pacific Northwest Regional group has organized what it calls 'Hydro-Tech Groups,' in two or three centers, for the purpose of holiday monthly meetings to discuss matters that bear chiefly on hydrology. Participation is mostly by hydrologists, but one of the papers presented at the December meeting dealt with the Montana Earthquake of August 17, 1959, and another with magnetic and electrical methods, especially in relation to hydrologic problems. The basis of the meeting might appropriately be broadened, and steps to that end will be taken during the next year. The oceanographers of Oregon State College and the University of Washington, and the very active group at the University of British Columbia, might conceivably give great impetus to this regional activity.

Chairman Melvin Ord of the Northwest Regional Committee is a member of the Committee for the National Western Meeting. The idea of holding annual national meetings in the West was met with considerable enthusiasm; however, the group felt that the regional meetings should be held as at present, except when the National Meeting is held within the Northwest Region.

Membership—Earl Droessler, Chairman, referred to the statistics in the General Secretary's report, and noted that, in spite of the inactivity during the summer, there had been a small gain in membership. Growth should be greater as activity is resumed during the fall and winter months. He indicated that Elliott B. Roberts had been recently designated Chairman of the Committee on Corporation Membership, and he expected that other additions to the Membership Committee would be made during the coming months. President Berkner noted that Annual Western Meetings should have a tendency to increase membership in areas where these meetings have impact, and that the General Assembly of 1963 should have similar effect.

The suggestion that the AGU establish a grade of 'Fellow' was discussed. Considerable sentiment has been expressed in favor of Fellowship for mature geophysicists whose horizons embrace a broad field. The Committee on Membership was asked to study this matter and to consult with some of the elder statesmen of AGU, including Walter H. Bucher, Leason H. Adams, Maurice Ewing, and W. D. Lambert. The thought was expressed that if such a grade is established, Officers of the Union and its Sections might appropriately be restricted to the 'Fellow' grade.

Also discussed was the idea that provision might be made for advancing Associate Members to Members without request by the Associate Member, but no action was taken.

Statutes and By Laws—Chairman, K. Hilding Beij. It was noted that the Preamble has long indicated the Executive Committee of the American Geophysical Union as the Committee on Geophysics of the National Research Council, and that the Preamble, as revised in the recent ballot, still continues this provision. Because the Executive Committee of the American Geophysical Union has not acted as the Committee of Geophysics of the National Research Council for several years, the question was raised as to whether or not this provision should be dropped. As it was not germane to the particular points on which revision of the statutes were being made, such a revision was not included in the last ballot. A motion was made and passed that:

> This matter be referred to the Committee on Statutes and By Laws for appropriate recommendations in light of these discussions and the facts of the situation.

Award of the William Bowie Medal, Maurice Ewing, Chairman—The Committee has not completed its deliberations on the designation of the Twenty-Third William Bowie Medalist. The Executive Secretary was requested to obtain this information as soon as possible, and to circulate it among the members of the Executive Committee, for their information. (The Committee has since advised that the Twenty-Third William Bowie Medalist is Keith Bullen of Australia.)

Resolutions, Helmut E. Landsberg, Chairman—The Committee did not report at this time, but it was voted that a resolution of thanks, as follows, be sent to the proper authorities of the University of Idaho, which acted as host to the Pacific Northwest Regional Meeting in Moscow, October 19–20, 1960:

> WHEREAS, the success of the Pacific Northwest Regional meeting at Moscow, Idaho, October 19–20, 1960 was due in a large part to the space and facilities generously provided by the University of Idaho, therefore be it
>
> RESOLVED, that the Executive Committee of the American Geophysical Union express its appreciation to the University of Idaho for the use of its meeting room, and request the General Secretary of the American Geophysical Union to express the thanks of the Union to the President of the University of Idaho.

Award in Geomagnetism and Aeronomy (John A. Fleming Award), Fred Agnich, Chairman—It was pointed out that the sum now available for this purpose is more than $5000, and it was felt that we should take some steps to make an appropriate award as soon as possible. The Committee should recommend, as soon as possible, whether the award should be as cash, a medal and a scroll, or in some other form. It was suggested that we authorize the Committee to set up standards and to take appropriate action, including the design of a medal. It was voted that:

> The Committee be thanked for its effective activity and to be urged to complete the fund and specifications for the Award as soon as possible.

Geophysical Abstracts—Designation of a new Chairman is pending. The report on this problem was presented earlier, in discussion of problems relating to oceanography.

Geophysical and Geological Study of Continents, George P. Woollard, Chairman—The report set forth in Appendix 11 was presented by title and accepted.

Study of the Metric System, Floyd W. Hough, Chairman—The Chairman has reported that the Committee is now inactive, but is serving as a stand-by Committee to be of assistance in legislative problems if and when such assistance should be requested. The last report of the Committee was presented at the meeting of last spring and published in the September issue of the *Transactions* (p. 477).

Planning on Planetary Science, Homer E. Newell, Jr., Chairman—A report of the Committee is published in the September 1960 issue of the *Transactions*, namely 'The President's Page' (page 407) and 'Highlights of the Planetary Sciences Program' (starting on page 430). Chairman Newell noted that the Committee had been organized in December 1959, and that it had held a meeting in February 1960 for discussing and making plans for participation in the annual meeting of April 1960. Newell reported also that plans have been made to participate in the Pacific Southwest Regional Meeting in late January 1961, at the University of California (Berkeley), and that a session is being planned in connection with the AAAS Meeting in New York, in December 1960. Plans for cooperation with the Section of Geomagnetism and Aeronomy are also being worked out in connection with the program of the Annual Meeting to be held in April 1961. The Executive Committee discussed the need and desirability of establishing a new section on Planetary Sciences. The President noted that further action seems desirable, in view of correspondence from AGU members, and that we must consider problems carefully, especially since the IUGG has now established a Committee

on Planetary Sciences. The Planning Committee on Planetary Science is to be the AGU's counterpart of the IUGG Committee on Planetary Science. It was noted that the present sections should not be robbed of their direct interests in space. If a new Section on Planetary Sciences is established it would serve to integrate those aspects of the space sciences involving lunar and planetary science that are not the direct concern of existing sections. A motion was made and passed that:

The Planning Committee on Planetary Science make a study, and report its recommendations on the problem at the spring meeting of the Council of AGU.

Reports of Sections

Seismology—President Murphy noted that he had received word recently from Robert Stoneley that the International Seismological Summary has run out of funds and needs $5,000 more as quickly as possible from some source. It was noted that the location of epicenters is now to be done on a regional basis and in due course the UNESCO Computation Center in Rome should be able to help. The main problem with respect to Stoneley is the completion of the gap from 1953 to 1960. After extensive discussion a motion was made and passed that:

The Earth Sciences Division should discuss the situation with ISS, and ascertain what course of action would be most effective.

Volcanology, Geochemistry, and Petrology—L. T. Aldrich noted that international geochemistry is being organized along three lines, namely (1) through the International Union of Pure and Applied Chemistry, (2) through the IUGG, and (3) through an Inter-Union Geological Congress. He felt that this was being done with a minimum of overlap and with the proper recognition of the various specialized interests. He noted that a joint session of the Sections of Meteorology and Volcanology, Geochemistry, and Petrology is being planned for the Annual Meeting, and discussed the feasibility of a similar session being worked out with Hydrology. Geochemistry has close relationship also with the photochemistry of the outer atmosphere, the planetary sciences, and oceanography.

Hydrology—Ralph Wilson reported that the Section of Hydrology is working closely with the World Meteorological Organization for the sessions of hydrology being planned for the next Annual Meeting, and that some of the sessions will undoubtedly be held jointly with other sections.

(Editor's note)—The President of the Section of Hydrology, Walter Langbein, has been serving as Chairman of the Panel of Hydrology of the Federal Council on Science and Technology. He had planned to present a progress report on the Panel's activities, but could not do so at the time of the meetings; however, the report has since been released, and is added here, as Appendix 12.

National Research Council Reports

Division of Earth Sciences, Edward B. Espenshade, Jr., Chairman—The Chairman expressed the hope that at future meetings of the Executive Committee or Council reports might be available on oceanography relative to the Indian Ocean activities, on the work of the seismic group, and on the work of the Moho group, which is now commencing tests in the Pacific off the coast of Mexico.

Affiliated Organizations

American Geological Institute, James R. Balsley and Walter H. Bucher, Representatives—The proposed plans, and resulting discussions among the geological organizations regarding reorganization of the American Geological Institute were presented. It was noted that the trend in AGI is to grow increasingly professional rather than scientific, and that the Society of Exploration Geophysicists had given notice that it will withdraw from the AGI if the new constitution is adopted. The feeling was expressed that AGI will increasingly disassociate itself from the objectives of the American Geophysical Union. The question was raised as to the usefulness of continuing formal relations between AGU and AGI. President Berkner pointed out the dangers of appropriating the term 'geoscience' for use in a purely geotechnological and geoengineering sense. The term should be used only in its broad connotation. It seems somewhat probable that the new organization, or the successor to AGI, will withdraw entirely from affiliation with the National Research Council–National Academy of Sciences.

It was noted, also, that a move is on foot to organize an International Geological Union following the general pattern of the IUGG. If such Union is organized it will probably become a part of the International Council of Scientific Unions ICSU. Such development may well go far to distinguish the scientific, the technological and the engineering aspects of geology, and to promote scientific opportunity in the geologic field.

The discussion showed that each of these moves has definite advantages. Geology and geophysics as sciences should come closer and closer together to form the geosciences properly; that part of geology that is devoted to purely engineering applications should be recognized properly as a professional activity that is derived from one aspect of the geosciences.

New Business

Vice President Pritchard of the Section of Oceanography outlined the plan for a visiting scientist program in oceanography, and noted that President Munk had designated Norris W. Rakestraw as Chairman of a Committee for this purpose. Through the office of AGU it has been estimated that a grant of about $15,000 would be required to accomplish the purpose for one year. It was thought that this might be the first step in establishing a broader

program of visiting scientists in various aspects of geophysics. Meteorology is already covered by a successful program of this kind under the American Meteorological Society. It was moved and approved that:

The American Geophysical Union seek a grant from the National Science Foundation of an amount up to $15,000 to carry on this work for a year.

The recommendation of Woodrow Jacobs and Earl Droessler to establish a Committee on Geophysical Data was considered (see Appendix 13). This committee would have as its purpose, not only the consideration of the data program of the World Data Center established by IGY, but a broader program for making these data and data from other sources available and useful for research scientists in various branches of geophysics. It was noted that we need a 'watch-dog committee' to see that the work gets done. A motion was made and passed that:

An *ad hoc* Committee on Geophysical Data should be established under the Chairmanship of Woodrow Jacobs, with Helmut Landsberg, Alan Shapley, and Earl G. Dressler as members (By subsequent action Hugh Odishaw and Pembroke Hart have been added to the Committee).

The meeting of the Executive Committee adjourned at 17h 10m.

A. Nelson Sayre, *General Secretary*
Waldo E. Smith, *Executive Secretary*

Appendix 1—Report of the Committee of Tellers

James N. Jordan, *Chairman*

Three proposals were recently placed before the membership relating to changes in the Statutes. The Committee of Tellers met at the office of the American Geophysical Union at 09h 00m on September 30, 1960, to count the ballots concerning these changes. The following assortment of ballots was considered:

Total ballots received		2224
Rejected ballots:		
Ballots from delinquent members	18	
Ballots from non-citizens of US	31	
Ballots from student members	39	
Defective Ballots (unmarked, or intent of voter not clear)	4	92
Qualified ballots tabulated		2132

The outcome with respect to the three proposals was as follows:

	For	Against
Proposal I	2097	32
Proposal II	2059	70
Proposal III	2103	24

The regular members of the Committee present were: Howard Oliver, James F. Lander, B. C. Byrnes, R. W. Seaton, and James N. Jordan. Members *pro tem* present were: Martin Kane and William Dempsey.

Appendix 2—Report on Preliminary Plans for XIIIth General Assembly of IUGG

Thomas F. Malone

On October 12 Professor Joseph Kaplan, Executive Secretary Waldo Smith, and I visited Stanford University and the University of California at Berkeley to investigate the suitability of these two universities as sites for the XIIIth General Assembly, in 1963. In our plans, we were thinking of a total attendance of about 3000. Particular attention was paid to the facilities for providing delegates and guests with lodgings, and meals, and for meeting rooms. The principal results of our investigation follow.

Stanford University—Accommodations on a double room basis are available in University dormitories for 3000 people. Children can be accommodated. In terms of 1960 prices the cost per day for each person in a double room, with maid service once a week, would be $7.16. The same facilities with daily maid service would be about $8.00 per day. An overflow, on a double room basis, is available for approximately 400 additional people in barracks at Stanford Village, about three miles from Stanford University. Hotels and motels in the Palo Alto area have a capacity of almost 700. There are ample cafeteria facilities on the campus.

Three large auditoria are available, with capacities of 1739, 719 and 500 respectively. Also available are one meeting room with a capacity of 350, four meeting rooms with a capacity of 150–300, six meeting rooms with capacities of 101–150, twenty-nine meeting rooms with capacities of 51–100, and

sixty-six classrooms with capacities of 16–50. Gatherings larger than about 1700 would have to be held outside, but there are suitable facilities for these.

The most suitable time from the standpoint of summer school schedules would be during the two-week period beginning on August 26. A resident professional staff may be available by 1963 to handle the housekeeping details of the meeting.

University of California at Berkeley—The Berkeley campus will have dormitory facilities that will accommodate about 2700 individuals on a double room basis, and of these, about 2300 would be available for the Assembly. An additional 500 hotel spaces in Berkeley and a much greater hotel capacity in nearby San Francisco may be obtained.

Superb cafeteria facilities are available on the campus. Banquet facilities to accommodate two to three thousand will probably be available in the new student union which is just being completed.

Prices for campus accommodations are $7.00 per day for room and meals (on a double room basis), and $1.00 additional for single rooms; daily maid service is included.

More than enough lecture halls and classrooms, in great variety are available to accommodate participants in the General Assembly. The Men's gymnasium could accommodate about 8000 people, and the outdoor Greek theater could accommodate up to 10,000.

A full-time resident staff, capable of handling the housekeeping details in connection with the General Assembly will be available.

On October 13 we visited the campus of the University of California at Los Angeles and that afternoon, Waldo Smith and I visited the University of Southern California.

University of California at Los Angeles—Dormitory facilities on a double room basis could accommodate about 1700 individuals. No count was available on the number of motel and hotel rooms in the immediate area. Ample cafeteria service is available on the campus. The cost, lodging and meals, is estimated in 1960 prices at $7.00 per day.

More than enough meeting rooms of all sizes are conveniently and centrally located on the campus.

A resident professional staff is available to handle the housekeeping details of the meeting.

University of Southern California—The facilities on the campus of the University of Southern California are inadequate to accommodate a meeting of this size. The administration of the school showed considerable interest in being host to the Assembly, and generously offered to explore the possibilities of using nearby municipal facilities that would provide more than enough meeting rooms.

Local climatological data for August and September for selected California stations were kindly made available by Corday Counts, Meteorologist in Charge, U. S. Weather Bureau, San Francisco. The tabulation follows:

	TEMPERATURE, °F					PRECIPITATION	
Location	Mean max	Mean min	Highest	Lowest	Average no. of days ≤90°	Mean monthly	Average no. of days ≤.01″
San Francisco (City Office)							
August	65	54	87	47	0	0.01	1
September	68	55	97	48	1	.13	1
Berkeley							
August	69	55	90	47	<1	.04	<1
September	71	55	98	48	1	.13	2
Palo Alto							
August	76	54	96	46	1	.03	<1
September	77	52	99	39	3	.06	1
Los Angeles (City Office)							
August	84	62	101	53	3	.02	1
September	82	60	110	51	6	.27	1

Recommendation—It is recommended that

(a) Preassembly meetings, such as that held in Copenhagen by IAGA, be held at Stanford University for *Hydrology*; at Scripps Institution of Oceanography (La Jolla, Calif.) for *Oceanography*; and at University of California (Los Angeles) for *Geomagnetism and Aeronomy*, and for *Meteorology*.

(b) The General Assembly be held at the University of California, Berkeley, during the last week of August and the first week of September.

Appendix 3—Report of Special Committee on the Problems and the Future of the Journal of Geophysical Research

PHILIP H. ABELSON, *Chairman*

In a letter dated August 9, 1960, President Berkner appointed me Chairman of an *ad hoc* Committee charged with examining publication policy with respect to splitting the *Journal of Geophysical Research*. The questions raised were:

1. The financial problems involved.
2. The attitudes of the various Sections toward the move.
3. Possible future effects of this split on geophysical interests.
4. The printing problem, including a possible change in format.

Members of the Committee included: Aeronomy, L. R. Alldredge; Hydrology, W. B. Langbein; Geodesy, C. A. Whitten; Oceanography, D. W. Pritchard; Tectonophysics, G. J. F. MacDonald; Meteorology, F. W. Reichelderfer; and Seismology, J. A. Peoples, Jr.

This committee met October 7, 1960. All members were present except Dr. Whitten, who had conveyed his opinions to the Chairman ahead of the meeting.

Six members of the group were opposed to splitting the Journal. Langbein and Pritchard favored a change in policy, but neither indicated that immediate drastic action was essential. Langbein indicated that, although the number of papers in hydrology has not decreased, and the Section of Hydrology maintains a vigorous program to stimulate the publication of research papers in the *Journal*, the problem is in part a dissatisfaction with the diminished proportion of hydrology papers.

The majority view was based on the following points. There is a very important educational value in having all aspects of geophysics covered in one journal. The present *Journal* is in many hundreds of college libraries all over this country. Fragmentation would strike a serious blow at attempts to give a unified treatment of geophysics. Specialized geophysical publications, such as the *Journal of Marine Research*, are in about one-fifth as many college libraries.

Another important aspect is education at the post-doctoral level, where physicists and others coming into geophysics should be exposed to all facets of the subject.

Detailed examination of modes of splitting the *Journal* indicates that any separation of subject matter into parts will destroy possible opportunities for cross-fertilization, and that a new arrangement is likely to result in a whole new set of bitter complaints.

Both the *Physical Review* and the *Proceedings of the Physical Society of London* considered a split, but both withdrew the suggestion because of difficulties in drawing the lines between subject material.

The minority view was that splitting of the *Journal* was desirable because papers on hydrology and oceanography are buried in too much other material, and because the *Journal* is too voluminous and occupies too much shelf space.

The following actions were agreed on. A questionnaire will be circulated among oceanographers and hydrologists to determine more accurately what the membership of the Sections really desire in the way of content and organization of a journal. It was also suggested that papers of interest to hydrologists and oceanographers be reprinted as a group in a separate volume, perhaps once or twice a year. The questionnaire will inquire as to the interest in such a volume, and the willingness to carry the cost. This study will be accomplished before the 1961 annual meeting.

The editors have agreed, as an experiment, to segregate hydrologic and oceanographic papers in alternate issues of the Journal. However, papers on other aspects of geophysics will continue to appear in all issues.

In view of the outcome of the meeting, it did not seem appropriate to consider the financial problems involved, nor did discussion of a change in format seem desirable now.

The Committee agreed to meet next April to consider implementation of such recommendations as the hydrologists and oceanographers may wish to make at that time.

Appendix 4—Report of the Editors, Journal of Geophysical Research

PHILIP H. ABELSON AND JAMES A. PEOPLES, JR.

Editor Abelson has been appointed Chairman of an *ad hoc* committee to consider the future of *JGR*, especially as this relates to the possible division into two parts or series, and other changes to meet the problem of increased size. Analysis of the issue of August 1960 issue of *JGR* (total, 360 pages including unnumbered pages), divided into two issues of 180 pages each, shows that an added cost of $1000 would be added to our bill, which for that issue, was $10,325. This is roughly 10%.

During 1960 the *Journal of Geophysical Research* will publish approximately 4280 pages. This may be compared with a total of 1409 in the predecessor journals in 1958 and 2460 pages appearing in the

Journal in 1959. In Table 1 is displayed an analysis of the content for 1958, 1959, and 1960. It can be noted that all Sections of the Union have contributed an increased number of pages.

Table 1—*Comparison of Number of Printed Pages of Geophysical Publications in 1958, 1959, and 1960*

Field	1958 AGU	1958 JGR[a]	1959 JGR	1960 JGR
General	38		79	105
Geodesy	51		171	260
Seismology	37		107	213
Meteorology	101		177	450
Geomagnetism and Aeronomy[b]	38	588	1237	2106
Oceanography	115		104	262
Volcanology, Geochemistry, and Petrology	56		164	192
Hydrology	345		326	430
Tectonophysics	40		95	265
	821	588		
Total pages	1409		2460	4283

[a] Adjusted to reflect fact that old *JGR* had only two-thirds as many words per page as new journal.
[b] This classification includes Geomagnetism, Aeronomy, and Space Physics (all very broadly defined).

The co-editors do not envision future growth at the exponential rate experienced during the past two years but anticipate a more moderate increase to approximately 4800 pages. To avoid overrunning this level may require a tougher policy and possibly rejection of some meritorious papers. In addition, we shall probably be unable to publish review papers and may be forced to scrutinize closely the content of any symposium material.

As we face the possibility of a more stringent approach, we believe that our selection of papers should be guided by the following considerations: (1) Emphasis on interdisciplinary contributions. (2) Selection of material interesting to a maximum number of readers. (3) Potential long-range significance. (4) Prestige accruing to the *Journal* by reason of distinction of contributor or contribution (particularly applicable to items of foreign origin). (5) Attention to the special needs of Sections, such as Hydrology and Oceanography.

The Editors have been fortunate in having the best of cooperation from a large number of individuals—associate editors, reviewers, and particularly the editorial staff, including Mrs. Rowena Peoples at Kansas, Mrs. Lucile Stryker and Mrs. Virginia Rapport of the Carnegie Institution of Washington, and A. David Singer, Miss Marjorie Imlay, and Miss Dolores Thomas of the Geophysical Laboratory staff.

Appendix 5—Report of the Russian Translation Board

PERRY BYERLY, *Chairman*
W. S. JARDETZKY, *Translation Editor*
WERNER A. BAUM
WALTER B. LANGBEIN
JOHN LYMAN
F. W. REICHELDERFER
A. E. SCHEIDEGGER
WALDO E. SMITH
VICTOR VACQUIER

Izvestiya—In the interval since the meeting of the Executive Committee in April, the English edition of the 1959 series of *Izvestiya* has been completed, and work is well under way on the 1960 series, the first number of which should be released by the time of the Executive Committee meeting. The schedule has been set up so that by the end of this year we shall be caught up as nearly as possible, the English edition following the release of the Russian edition by five or six months. A grant of $57,730 was approved by the National Science Foundation for carrying on this work; $20,000 of this has already been received.

The excess numbers of *Izvestiya* for 1957, which had been received from Pergamon Press in England, were distributed during the summer months as a promotional program to increase subscriptions. About 35 subscriptions are traceable to this endeavor; most of them were subscriptions and purchases to cover the four years 1957 to 1960 inclusive, making this a decidedly worthwhile endeavor. The account was closed with Pergamon Press, and with the receipts from subscriptions, a balance of about $1500 is credited to this project; we will need to negotiate with the National Science Foundation on this balance, expecting to make it applicable to the continuance of this endeavor. A report covering the series for 1957 and 1958 will soon be filed with the Foundation.

Trudy—Translation and publication of numbers 37, 38, 39, and 40 of *Trudy* of the Geophysical Institute of Moscow have been undertaken as a project with the Consultants Bureau, with the aid of a grant from the National Science Foundation.

Numbers 37, 38, and 39 have been released. We have been attempting to secure from the Consultants Bureau information on their sales thus far, and on the reasons for the delay on No. 40. This information is not yet available. Since the initiation of this project, attempts have been made to determine subsequent titles of numbers of this series; these were without success until the Twelfth General Assembly was held in Helsinki. It was then found that the Geophysical Institute was reorganized following the issuance of No. 40 and divided into two parts, and now they are issuing two new *Trudy* series—one for the Institute of Physics of the Earth, the other still unidentified. Several numbers of the new series were on display in Helsinki and will be considered for translation at the next meeting of the Board.

Geodesy and Cartography—Applications for funds to publish an English edition of this was filed with the National Science Foundation; it was approved in the amount of $25,466. The work on this project is now proceeding under arrangements with Royer and Roger. Nos. 1 and 2 of the 1959 series have been translated, reviewed by our translation consultants, and returned to Royer and Roger for issuance of the English edition. There is some indication that the project will receive support also from at least one other government agency.

Meteorology and Hydrology—Because of the marked differences of opinion among meteorologists and hydrologists, no steps have been taken to secure a grant for the publication of an English edition of this periodical. The American Meteorological Society is translating what they deem to be the important papers, but these seem to receive very meager distribution, and so tend to be lost. There is a strong feeling on the part of many hydrologists and meteorologists that steps should be taken to clarify this situation. The Board seeks the guidance of the Executive Committee on this matter.

Chinese scientific literature—Another matter that should be called to the attention of the Executive Committee is that during the spring a conference was held at the National Science Foundation to which Russian translation representatives were invited to see what could be done about handling Chinese scientific literature. The outcome was the development of a symposium on Chinese scientific literature to be held by the AAAS at its December meeting in New York. J. Tuzo Wilson has been invited, on the initiative of AGU's representative, to outline the work being done in the hard-rock phases of geophysics. Malcolm Rigby, of the American Meteorological Society's abstracting project, will summarize the work in the fluid phases of geophysics. Our representative on this committee is Walter B. Langbein.

Proposed translation of Russian Oceanographic publications—Under date of May 20, a copy of a letter to Harrison Brown (Chairman of the NAS Committee on Oceanography) came from Warren Wooster of the Scripps Institution, noting the great deficiency in translated oceanographic papers. Wooster offered suggestions with regard to translating various publications, including the *Referativnyi Zhurnal*, *Trudy Instituta Okeanologii*, and selected papers from multiple sources as a new publication to be called *Soviet Oceanography*. In responding to this on May 31, in the absence of a meeting of our Russian Translation Board, the Executive Secretary noted that our own experience through the translations of *Referativnyi* journals is that the resulting English abstracts, having passed, for example, from French to Russian to English, are not satisfactory, that the abstracts from the Russian journals themselves are brief and indicative rather than informative, and that, in general, cover to cover translation of *Referativnyi* journals would overemphasize the work that the Russians are doing, and so would be likely to build up a propaganda weapon for them.

Moreover, the American Meteorological Society has now broadened the scope of its Meteorological Abstracts to include most, if not all, of oceanography, giving worldwide coverage and taking care of the need in this field.

With regard to the *Trudy* of the Institute of Oceanology, Wooster's earlier letter suggested that this be divided between the American Society of Limnology and Oceanography and the American Geophysical Union. This is perhaps, the best single Russian publication in Oceanography. Production and distribution of an English edition would be complicated by trying to administer it through two groups. Either organization should do this with the moral support of the other.

The third idea, namely, to issue a journal of collected translations of papers in oceanography would create a big job. To avoid this, perhaps informative abstracts of the papers should appear in an appropriate journal, and only those that are specifically requested should be translated in full, and for limited distribution. Is there wisdom in establishing a new journal under a title such as *Soviet Oceanography*?

The Russian exhibit of scientific literature in Helsinki included a series that seems not to be available in the United States. This is the *Trudy* of the Hydrophysical Institute of the Sea. No. 18, entitled 'Theory of Wave Currents,' published in 1958 was on display. No. 2 of the series bears a 1949 date. Perhaps this publication likewise should be given consideration if it can be obtained.

On October 11, Richard Vetter of the Office of the Committee on Oceanography of the Academy called and indicated that the Committee, after some delay, feels that something should be done with regard to foreign oceanographic literature, thus tending to support the recommendations of Wooster as set forth in his letter of June 17. This matter should appropriately be laid formally before the Russian Translation Board, to be followed by recommendations, and perhaps action, of this Committee by mail ballot. An expression of opinion and discussion would seem appropriate at this meeting.

Appendix 6—Report of the Committee on Budget

JOHN C. REED, *Chairman*

L. T. ALDRICH L. O. QUAM

A. The staff has prepared a proposed budget for the year. Although it has not yet received the attention of the Budget Committee, it is presented below for action.

Our consulting accountant has been at work on the books, and has revised and up-dated our bookkeeping system in order that we may be in a position to establish our financial status easily in its several projects from month to month. Although the changeover has been made, a monthly statement was not issued for July or August, but one has been prepared for three months, to the end of September 1960.

Schedule A

BALANCE SHEET, SEPTEMBER 30, 1960

Current Assets:			
Cash—Regular Account			$ 15,947.43
Cash—Savings Accounts			62,604.34
U. S. Treasury Securities, at cost			138,296.10
Billed Receivables			18,123.36
Unbilled Receivables			8,000.00
Deposits (Postage)			517.78
			$243,489.01
Current Liabilities:			
Accrued Printing Bill		$ 13,500.00	
Accounts Payable		4,832.82	
Deferred Income—1961 & 1962		1,032.64	
Deferred Income—1960 Dues		12,665.50	
Deferred Income—1960 Subscriptions		11,514.00	
Funds:			
T. M. & E. Fund		5,242.55	
JGR Fund	$ 49,931.65		
Trudy	3,197.12		
Izvestiya 1957	1,510.98		
Izvestiya 1958	10,771.51		
Izvestiya 1959	10,228.55		
Izvestiya 1960	16,792.35		
Izvestiya 1961	(120.00)		
Monograph No. 3	1,741.09		
Monograph No. 4	4,846.69		
Monograph No. 5	(572.69)		
Asia Foundation	2,014.93		
IUGG Triennial Report	1,838.36		
Geodesy and Cartography	24,751.12		
Meteorology and Hydrology	(14.75)	$126,916.91	$175,704.42
Excess of Current Assets over Current Liabilities			$ 67,784.59
Office Equipment			4,754.70
Surplus			
Permanent		$ 21,692.44	
Operating			
Balance June 30, 1960	$ 51,833.68		
Less Deficit for quarter ending Sept. 30, 1960	986.83	$ 50,846.85	
Net Assets			$ 72,539.29

Schedule B

STATEMENT OF INCOME

(Administration Account)

July 1, 1960 to September 30, 1960

(with Proposed Budget for Fiscal Year Ending June 30, 1961)

	Budget 1960–1961	Actual to Sept. 30, 1960
Revenues:		
Dues (30%) (Schedule 4)	$18,240.00	$ 3,798.77
Monograph sales (Nos. 1 & 2)	400.00	99.37
Interest income	6,000.00	1,674.01
Miscellaneous income	500.00	144.73
Overhead earned on grants:		
Monographs	50.00	19.14
Russian translations	11,000.00	3,399.83
Triennial Report	150.00	135.01
Asia Foundation	250.00	57.62
Overhead charged to projects:		
Journal of Geophysical Research (Schedule 2)	27,825.00	6,318.51
Transactions (Schedule 3)	1,980.00	624.10
TOTAL	$66,395.00	$16,271.09
Charges: (Administration Expense)		
Salaries, FICA & Ret. Contribution	$50,000.00	$13,229.07
Equipment	2,000.00	
Promotion	1,500.00	
Office supplies and expenses	3,000.00	555.96
Communications	3,500.00	428.43
Premise	7,800.00	1,936.80
Professional services	900.00	
Travel	2,000.00	750.00
Bowie Medal	130.00	2.44
President's Fund	100.00	
Membership:		
Printing and mailing	600.00	246.95
Meetings	2,100.00	
Committee and sections	400.00	4.00
Loss (Gain) on Transactions activities (Schedule 3)	(6,420.00)	104.27
TOTAL	$67,610.00	$17,257.92
Excess of Charges over Revenues	($1,215.00)	($ 986.83)

Schedule 1

PERMANENT FUND

July 1, 1960 to September 30, 1960

Fund Balance on July 1, 1960		$21,419.44
Add:		
Contributions	$ 91.00	
Interest on investments	182.00	273.00
Fund Balance on September 30, 1960		$21,692.44

Schedule 2

JGR FUND ACTIVITIES

For Quarter Ending September 30, 1960, Revised October 7, 1960 and Proposed Budget for Fiscal Year 1960–1961

	Proposed Budget	Actual to Sept. 30, 1960
Fund Balance on July 1, 1960	$ 55,764.00	$55,764.26
Revenues:		
Dues (50%)	$ 30,400.00	$ 6,332.50
Subscriptions	40,000.00	10,184.35
Page charges	84,000.00	15,525.00
Reprints	15,000.00	6,752.00
Back issue sales	7,200.00	1,849.90
Advertising	12,000.00	1,965.56
Grants	16,750.00	
Total	$205,350.00	$42,609.31
Charges:		
Editorial Office:		
Salaries	6,800.00	1,364.76
Honoraria	4,000.00	1,000.00
Expenses	3,000.00	824.96
Salaries (AGU office)	13,000.00	2,446.94
Printing and mailing	150,000.00	34,707.72
Materials, supplies, and services	500.00	84.05
Reprints	7,200.00	1,694.98
Promotion	1,000.00	
Administration (15%)	27,825.00	6,318.51
	$213,325.00	$48,441.92
Net Change in Fund	(7,975.00)	(5,832.61)
Fund Balance at End of Period	$ 47,789.00	$49,931.65

Schedule 3

TRANSACTIONS ACTIVITIES

July 1 to September 30, 1960

(with Proposed Budget for Fiscal Year Ending June 30, 1961)

	Proposed Budget 1960–1961	Actual to Sept. 30, 1960
Revenues:		
Dues (20%)	$12,160.00	$2,533.00
Subscriptions	6,000.00	1,330.39
Reprints	200.00	31.00
Back issue sales	2,000.00	475.10
Advertising	1,200.00	303.00
IGY Bulletins	8,000.00	2,033.27
Miscellaneous	40.00	8.00
Total Revenues	$29,600.00	$6,713.76
Charges:		
Salaries (AGU office)	$ 5,000.00	$1,360.28
Printing and Mailing	8,000.00	2,777.38
Materials, Services, and Supplies	100.00	
Reprints	100.00	23.00
IGY Bulletins	8,000.00	2,033.27
Administration (15%*)(Schedule B)	1,980.00	624.10
Total Charges	$23,180.00	$6,818.03
Excess of revenues over charges	$ 6,420.00	($ 104.27)

*Exclusive of IGY Bulletins

Schedule 4
DISTRIBUTION OF DUES
For Fiscal Year 1960–1961

Classification	Yearly Rate	No.	Proposed Budget Amount	Actual to Sept. 30, 1960
Dues:				
Members (reg. & assoc.)	$ 10.00	5500	$55,000.00	
Life members	0	100	0	
Student members	4.50	400	1,800.00	
Corporation members	100.00	40	4,000.00	
Contributing members	500.00	0	0	
Sustaining members	1,000.00	0	0	
Benefactors	5,000.00	0	0	
			$60,800.00	$12,665.00
Allotment				
To JGR	50%		$30,400.00	
To Transactions	20%		12,160.00	
To Administration	30%		18,240.00	
			$60,800.00	

ESTIMATED BALANCE SHEET, JUNE 30, 1961

Current Assets:			$280,708.00
Current Liabilities:			
Accounts Payable		$ 35,500.00	
Deferred Income		53,000.00	
Funds:			
T. M. & E. Fund		5,500.00	
JGR Fund	$47,790.00		
Trudy	3,000.00		
Izvestiya 1957	0		
Izvestiya 1958	0		
Izvestiya 1959	0		
Izvestiya 1960	0		
Izvestiya 1961	50,000.00		
Monograph No. 3	1,800.00		
Monograph No. 4	5,000.00		
Monograph No. 5	0		
Asia Foundation	500.00		
IUGG Triennial Report	0		
Geodesy and Cartography	10,000.00	118,090.00	212,090.00
Excess of Current Assets over Current Liabilities			$ 68,618.00
Office Equipment			5,000.00
Surplus:			
Permanent		$ 23,000.00	
Operating:			
Balance June 30, 1960	$51,833.00		
Less Deficit for year ending June 30, 1961	(1,215.00)	50,618.00	
Net Assets			$ 73,618.00

(B.) The dues and subscription years now correspond to the calendar year, but the fiscal year for the budget and accounts is July 1 to June 30. This leads to much confusion that may seem minor but the cumulative effect is such that our Accounting Consultant recommends that we change to the calendar year throughout, preferably as of January 1, 1961. This will mean that the budget for the year will be presented ordinarily at the autumn meeting instead of the spring meeting. It has long been noted that the financial statement presented in the spring is always on the optimistic side because

most of the income for subscriptions and dues has been received but most of the expense for the calendar year that is to come from that income lies ahead, roughly half for the calendar year in the next fiscal year. The recommended change will also eliminate that awkward situation. It is requested that appropriate action be taken.

(C.) At the Executive Committee meeting on April 26, a motion was made and passed that an annuity of $10,000 be purchased on behalf of any senior staff member whose service predated the initiation of the NAS retirement plan by AGU by more than five years, such annuity to be paid to the annuitant upon his retirement in appropriate annual installments. Difficulty has been encountered in securing this annuity on the tax-free basis intended; it must be integrated into a retirement plan approved by the Internal Revenue Service, and thus become a part of the TIAA plan recently adopted by the NAS. So much time has been required for the changeover by NAS that such specific problems have been deferred. Business Manager Meid of the National Academy advises that the Academy has this under study on two bases: (1) to determine what can be done in general, as this problem comes up for those approaching the nominal retirement age of 65 and for whom funds might be available to support additional retirement income, and (2) to determine what can be done, within the Internal Revenue Code, under which an individual may take a voluntary cut in pay and have the amount of the cut transferred to his retirement fund without current tax. The question is being raised with the Academy's attorney, as to whether or not the latter (2) can be accomplished. In any case, Mr. Meid recommended that the annual payment be placed in an appropriate fund to draw interest until this matter can be clarified. He also notes that an annuity of $10,000 involves a payment of about $66 a month to an annuitant if he retires at the nominal retirement age of 65.

Appendix 7—Report of Special Committee on Dues and Subscription Rates

EARL G. DROESSLER, *Chairman*

L. R. ALLDREDGE
B. F. HOWELL, JR.
WALTER B. LANGBEIN
JOHN C. REED

A year ago, Earl Droessler was designated as Chairman of an *ad hoc* committee for the study of dues. At the Executive Committee Meeting of last April his committee recommended an increase of dues from $10 to $13 per annum, noting that a minority of the Committee opposed any increase of dues at this time. A motion was made to accept and table the report but that this should be taken up again after the new accounting system is put in effect. This action affects also the subscription rates. The report of last spring was not published with the minutes, but is cited on page 467 of the September 1960 issue of the *Transactions*. The full report is as follows:

The Special Committee on Membership Dues recommends to the Executive Committee of the American Geophysical Union that the dues of the members and associate members be increased from $10.00 to $13.00 per annum.

The majority view (Alldredge, Howell, and Reed) favored an increase for the following reasons: (1) a projected margin of operating deficit of approximately $25 to $30 thousand after the NSF grant for the *JGR* runs out (budget estimates were provided by the Chairman of the Budget Committee); (2) the AGU dues are well on the low side when compared to other scientific societies, considering the services and publications received; and (3) if the publications are to continue to qualify for second class mail rates, AGU should comply with Postal Regulations, which state that the circulation of such publications 'must be limited to copies mailed to members who pay either as a part of their dues or assessments, or otherwise, not less than 50 percent of the regular subscription price...' The subscription price for *JGR* is $25.00.

A committee minority (Langbein) dissented from the increased dues recommendation, and opposed any increase at this time, expressing fear that the hydrologists would not support an increase and may leave the AGU in large numbers if dues are increased.

Appendix 8—Report of the Committee on Audit for the Fiscal Year Ending June 30, 1960

A. G. McNish, *Chairman*

A. P. Crary E. B. Roberts

On the recommendation of the Consulting Accountant and by approval of the Executive Committee, as set forth in the minutes, the Committee on Audit has not reviewed the financial statement on either the old cash basis or on the new accrual basis. The financial statement that follows was prepared under the guidance of, and was approved by, the Consulting Accountant.

UNAUDITED FINANCIAL STATEMENT ON THE NEW ACCRUAL BASIS FOR THE FISCAL YEAR ENDING JUNE 30, 1960

Balance Sheet, June 30, 1960;

Current Assets:			
Cash in Regular Account			$ 4,089.35
Cash in Savings Accounts			78,114.34
U. S. Treasury Securities, at cost			149,015.70
Accounts Receivable			16,258.79
Accrued Receivables: JGR (reprints)			18,173.89
Monograph No. 5			1,887.00
			$267,539.07
Current Liabilities:			
Accounts Payable		$ 35,690.04	
Deferred Income		52,812.96	
Funds:			
T. M. & E. Fund		5,242.55	
JGR Fund	$55,764.26		
Geodesy and Cartography	(4.25)		
Izvestiya 1957	2,794.79		
Izvestiya 1958	10,324.20		
Izvestiya 1959	26,315.24		
Izvestiya 1960	(3.50)		
Trudy	3,336.32		
Monograph No. 3	1,668.28		
Monograph No. 4	4,750.51		
Monograph No. 5	(1,909.02)		
Meteorology and Hydrology	(2.75)		
Asia Foundation	2,456.71		
IUGG Triennial Report	(1,535.54)	103,955.25	197,700.80
Excess of Current Assets over Current Liabilities			$ 69,838.27
Office Equipment			3,414.85
Surplus:			
Permanent		$ 21,419.44	
Operating: Balance at June 30, 1959	$17,934.19		
Income for Year Ending June 30, 1960	33,899.49	51,833.68	
Net Assets			$ 73,253.12

JGR Fund, June 30, 1960;

Jan. 1, 1959 NSF Grant G 6994	$ 60,000.00
Jan. 12, 1960 NSF Grant G 6994	40,000.00
	$100,000.00

	Oct. 30, 1958 to June 30, 1959	July 1, 1959 to June 30, 1960		
Revenues:				
Subscriptions	$22,922.31	$ 40,111.93*		
Back Numbers		1,549.22		
Reprints	5,100.00	63,884.50**		
Advertising	2,980.25	9,569.02		
C. I. W. Subsidy		3,000.00		
NAS-NRC Grant		400.00		
Dues Income 1959–60, 50%		28,229.00		
	$31,002.56	$146,743.67		
TOTAL REVENUES			$177,746.23	
Disbursements:				
Preliminary	$ 1,583.25	$ 3,627.46		
Proofreading	1,133.85	5,185.56		
Printing & Mailing	24,709.19	109,773.49		
Processing Subs, etc.	2,697.81	5,446.63		
Promotion	4,950.36	2,719.89		
Editor's Accounts:				
Salaries and Honoraria	6,774.31	9,686.69		
Stationary and Supplies	1,685.05	3,487.93		
Advertising	71.05	5.34		
Reprints	1,191.54	8,298.57		
Administration 15%	6,719.00	22,235.00		
	$51,515.41	$170,466.56		
TOTAL DISBURSEMENTS			$221,981.97	($44,235.74)
Fund Balance at June 30, 1960				$55,764.26

*Includes $3,853.40 transfer of funds from former *JGR*.
**Includes accrued income for reprints $18,173.89.

	1957 *Izvestiya Fund* June 30, 1960		
April 30, 1957: NFS Grant G 3622			$22,400.00
1957—May and June—Salaries and FICA	$ 169.30		
July 1, 1957 thru June 30, 1958:			
Salaries and FICA	742.06		
Advertising and Promotion	1,402.90		
Travel	602.32		
Subscriptions to Izvestiya	47.48		
Translations, Printing, and Mailing	3,216.00		
Postage	31.10		
July, 1958 thru June 30, 1959:			
Salaries and FICA	1,293.32		
Travel	90.29		
Translations, Printing, and Mailing	16,674.08		
Communications	3.19		
Subscriptions to Izvestiya	72.50		
Postage	48.35		
Promotion	95.68		
Administration (15%)	3,673.29		28,161.86
			($ 5,761.86)
Additional Grant (Nov. 24, 1958)		$16,036.00	
Sales		87.50	16,123.50
			$10,361.64
June 30, 1960:			
Sales		4,405.70	4,405.70
			$14,767.34

Salaries and FICA	95.91		
Translation, Printing, and Mailing	10,815.00		
Advertising credit allowed on printing bill	(500.00)		
Administration (15%)	1,561.64		11,972.55
Unexpended Balance, June 30, 1960			$ 2,794.79

1958 *Izvestiya Fund*
June 30, 1960

Dec. 31, 1958—Grant NSF G 7135			$44,835.00
Jan. 1959 thru June 30, 1959:			
Salaries and FICA	$ 496.26		
Translations including Editor	6,372.00		
Travel	854.50		
Communications	20.78		
Publishing Rights	420.00		
Administration (15%)	1,224.53		9,388.07
			$35,446.93
Sales		$ 122.50	122.50
			$35,569.43
July 1, 1959 thru June 30, 1960:			
Salaries and FICA	$ 1,387.46		
Printing and Mailing	17,612.27		
Materials, Services, Supplies	21.71		
Reprints	12.50		
Translations including Editor	6,892.00		
Travel	1,021.37		
Administration (15%)	4,042.10		30,989.41
			$ 4,580.02
Sales		5,724.18	
Reprint Sales		20.00	5,744.18
Unexpended Balance, June 30, 1960			$10,324.20

1959 *Izvestiya Fund*
June 30, 1960

Aug. 27, 1959—NFS Grant G 9523			$53,360.00
Sept. 15, 1959 thru June 30, 1960:			
Salaries and FICA	$ 1,748.25		
Printing and Mailing	11,607.34		
Materials, Services, Supplies	222.81		
Translations including Editor	15,354.00		
Administration (15%)	4,339.86		33,272.26
			$20,087.74
Sales		$6,227.50	6,227.50
Unexpended Balance, June 30, 1960			$26,315.24

Trudy Fund
June 30, 1960

July 14, 1959: NSF Grant No. 9320			$14,420.00
April and May, 1959: Materials and Supplies		$ 9.87	
June 30, 1960:			
Salaries and FICA		376.09	
Translating, Printing, and Mailing		8,698.50	
Materials, Services, and Supplies		34.52	
Translation Consultants		519.00	
Administration (15%)		1,445.70	11,083.68
Unexpended Balance, June 30, 1960			$ 3,336.32

Fund for Cincinnati Conference and Monograph No. 3
June 30, 1960

Nov. 1957 NSF Grant G 4584 to NAS-NRC Fund No. 8102			$4,000.00
Nov. 1957 thru June 1958:			
Travel	$ 3,036.67		
Salaries and FICA	200.00		
Materials, Services	7.20		
Overhead taken by NRC	486.58		3,730.45
			$ 269.55
June 30, 1958 thru June 30, 1959:			
Travel	$ 101.62		
Salaries and FICA	132.85		
Overhead taken by NRC	35.08		269.55
			-0-
Oct. 6, 1958 NAS-NRC Fund No. 8123 (Grant to NRC)			$3,550.00
March 1959–June 1959:			
Salaries and FICA	$ 876.18		
Printing–postcards	147.00		
Materials, Services, Supplies	17.20		
Postage	93.07		
Overhead taken by NRC	135.27		1,268.72
			$ 2,281.28
Sales		$ 574.74	574.74
			$2,856.02
June 30, 1959 thru June 30, 1960:			
Salaries and FICA	$ 112.13		
Printing	2,736.87		
Reprints	147.58		
Materials, Services, Supplies	10.91		
Overhead taken by NRC	327.77		3,335.26
			($ 479.24)
Sales		1,913.52	
Reprint Sales		234.00	2,147.52
Unexpended Balance, June 30, 1960			$1,668.28

Fund for Cambridge Conference and Monograph No. 4
June 30, 1960

Nov. 28, 1958 NSF Grant G 6502			$6,800.00
Thru June 30, 1959:			
Salaries and FICA	$ 735.84		
Travel	301.60		
Badges	20.00		
Communications	125.01		
Reporting Services	392.00		
Printing–Postcards	142.10		
Administration (15%)	257.48		1,974.03
			$4,825.97
June 30, 1959–June 30, 1960:			
Salaries and FICA	$ 544.20		
Printing and Mailing	2,376.20		
Materials, Services, Supplies	46.42		
Reprints	137.25		
Administration (15%)	465.61		3,569.68
			$1,256.29
Sales		$3,294.22	
Reprint Sales		200.00	3,494.22
Unexpended Balance, June 30, 1960			$4,750.51

Fund for Woods Hole Conference and Monograph No. 5
June 30, 1960

Sept. 28, 1958—NSF Grant G 6182			$25,000.00
Dec. 31, 1958 thru June 30, 1959:			
Salaries and FICA	$ 1,473.11		
Travel	7,709.89		
Communications	312.36		
Printing	1,300.68		
Woods Hole Meeting	260.00		
Administration (15%)	1,658.41		12,714.45
			$12,285.55
June 30, 1959 thru June 30, 1960:			
Salaries and FICA	$ 4,440.69		
Printing and Mailing	11,302.95		
Materials, Services, Supplies	957.26		
Reprints	1,070.45		
Honorarium (editor)	750.00		
Travel	35.68		
Administration (15%)	2,783.56		21,340.59
			($ 9,055.04)
Sales		$4,448.14	
Reprint Sales		2,797.88	7,146.02
Balance, June 30, 1960			($ 1,909.02)

Asia Foundation Fund
June 30, 1960

September 19, 1959—Grant			$2,500.00
Thru June 30, 1960:			
Materials, Services, Supplies		$ 37.64	
Administration (15%)		5.65	43.29
Unexpended Balance, June 30, 1960			$2,456.71

IUGG TRIENNIAL REPORT
June 30, 1960

Jan. 27, 1960 NSF Grant 11209		$5,000.00
Printing and Mailing	$5,156.89	
Materials, Services, Supplies	26.19	
Honorarium	500.00	
Administration (15%)	852.46	6,535.54
Balance, June 30, 1960		($1,535.54)

Transactions Activities
July 1, 1959 to June 30, 1960

Revenues:		
Dues	$ 7,039.62	
Subscriptions	5,867.71	
Back Issue Sales	23.75	
Reprints and Page Charges	554.00	
Advertising	553.83	
IGY Bulletins	13,181.42	
Miscellaneous	902.73	
Total Revenues		$28,123.06
Charges:		
Salaries	$ 3,633.70	
Printing and Mailing	10,654.46	
Reprints	453.90	
IGY Bulletins	11,290.80	
Miscellaneous	280.61	
*Administration (15%)	2,253.40	
Total Charges		28,566.87
Excess of Charges over Revenues		($ 443.81)

*Exclusive of IGY Bulletins

Statement of Income Administration Account
For Fiscal Year Ending June 30, 1960

Revenues:		
Dues	$28,090.20	
Monograph Sales (Nos. 1 & 2)	2,134.70	
Interest Income	6,685.17	
Contributions	2,306.57	
Miscellaneous	809.93	
Overhead Earned:		
Monographs	3,249.17	
Transactions	2,253.40	
JGR	22,235.00	
Russian Translations	10,912.52	
Triennial Report	852.46	
Asia Foundation	5.65	
		$79,534.77
Charges:		
Salaries and FICA	$20,114.84	
Office Supplies and Expense	2,674.03	
Communications	3,173.83	
Premise	6,206.64	
Travel	784.50	
Retirement Contribution	1,467.53	
Professional Services	1,122.60	
Membership Costs	9,407.58	
Miscellaneous	239.92	
Loss on *Transactions* Project	443.81	45,635.28
Excess of Revenues over Charges		$33,899.49

Appendix 9—Recommendations by Consulting Accountant

Dr. Lloyd V. Berkner, President
American Geophysical Union
1515 Massachusetts Avenue, N. W.
Washington, D. C.

Dear Dr. Berkner:

I have completed my study of the financial activities and accounting records of the American Geophysical Union and have recommended a system of records, procedures and reports which will furnish management the types of information suggested in your letter to Mr. Smith dated May 19, 1960.

The new accounting system was installed as of July 1, 1960, and is now operating very effectively. Monthly financial statements are available within a few days after the close of the month. After we have had some experience with the new system, we shall, of course, review its operation and make any refinements which are necessary.

The review of AGU's accounts was made primarily to establish an accounting system and did not constitute an independent audit of the accounts. In the course of this assignment, however, it was necessary to review past accounting procedures and transactions to establish account balances at July 1, 1960. In this limited review of transactions, the expenditures were properly documented and accounted for.

In view of the correctness of the records and the adequacy of the documentation as revealed in the limited review of the transactions, I would not recommend further audit of the AGU's accounts for the year ending June 30, 1960. I do recommend that the AGU require a regular annual audit as a part of its routine operations commencing July 1, 1960.

I am much indebted to Mr. Smith and his staff for their help in making this project very pleasant and successful.

Sincerely yours,

Oct. 21, 1960.

(signed) Garland C. Owens, C.P.A

Appendix 10—Report on Meeting of the Special Committee to Consider Annual Western National Meetings of AGU

The first meeting of the Committee on a Western National Meeting was held in Helsinki, Finland, August 1, 1960, during the General Assembly of IUGG. The following members were present: C. T. Elvey, B. Haurwitz, R. E. Holzer, W. W. Kellogg, and A. H. Shapley. Other members of the Committee are Eugene Bollay, Perry Byerly, P. E. Church, J. A. Jacobs, Gordon J. F. MacDonald, W. H. Munk, M. J. Ord, Saul Price, V. H. Regener, E. J. Workman. Invited participants were P. H. Abelson and Waldo E. Smith.

The Western Area was defined to include the continental area westward from the eastern slopes of the Rocky Mountains, Alaska, and Hawaii, specifically including Denver, Boulder, and Socorro.

It was decided to recommend that an annual meeting about six months from the Washington meeting dates is desirable.

Although it was suggested that the Western meeting might supplant present western regional meetings, it was pointed out that certain groups, such as the hydrologists, may want to continue their regional meetings. It was agreed that opinions of the present regional committees should be sought. David Todd of the Pacific Southwest Regional Committee expressed approval of the annual meeting idea. It was agreed also that the annual Western meeting should have national scope.

The desirability of holding the annual meeting concurrent with, or immediately following the annual West Coast meeting of the American Physical Society was discussed. It was felt that such meetings would stimulate common interests and contributions. No decision was reached, but it was agreed that UCLA would be a logical choice for the first annual meeting, in December 1961, inasmuch as the APS will be meeting there in late 1961.

It was agreed that the present regional committees should be kept informed of the progress of plans for a Western meeting, and that they should be represented on an arrangements committee for the meeting in December 1961.

Subsequent to the Helsinki meeting, Saul Price, President of the Geophysical Society of Hawaii (Mid Pacific Regional Group of ASU), was added to the Committee.

Joseph Kaplan, *Chairman*
W. W. Kellogg, *Secretary*

Supplementary note by Secretary Kellogg: The decision to have the next triennial Assembly of IUGG on the West Coast had not been made at the time of the Helsinki meeting of the Committee. It has since developed that the Assembly will be held in California; consequently this item will appear on the agenda of future meetings of the Committee.

Appendix 11—Report of the Committee on Geophysical and Geological Study of Continents

GEORGE P. WOOLLARD, *Chairman*

W. E. BONINI
R. A. GEYER
SIGMUND HAMMER
J. C. HARRISON
P. M. HURLEY
M. J. S. INNES
H. R. JOESTING
GORDON G. LILL
PAUL L. LYONS
J. A. PEOPLES, JR.
FRANK PRESS
DONALD A. RICE
NELSON C. STEENLAND
J. TUZO WILSON

J. LAMAR WORZEL

The activity of the Committee this year has been centered in the following four general realms of study: field mapping, data analysis, preparation of maps and scientific aid. The fields of study can be described briefly as gravimetric, magnetic, seismic, and geologic.

Support in the form of a grant from the Science Foundation was obtained by the Chairman of the Committee to complete the compilation and adjustment of gravity data for use in preparing a Bouguer gravity anomaly map of the United States. This program is now well advanced, and it is hoped that a proof map will be available before the next annual meeting. Under a grant from the Wisconsin Alumni Research Foundation a systematic study was started of the relations between the depth of origin of magnetic anomalies of regional extent and seismic layering in the upper portions of the crust. At this writing the results look quite good, and, if the relationship is general, magnetic data may prove to have considerable value for studying crustal compositional changes.

Although support under Project VELA UNIFORM of the Advanced Research Projects Agency was given to the U. S. Geological Survey to investigate crustal structure, the only refraction work of this nature carried out during the year was that of the non-governmental groups who have engaged in this line of investigation for several years. As was the case last year, the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, and Princeton University, joined the group at the University of Wisconsin in carrying out a continuous refraction profile study in Montana. The work this year was designed to give more detail concerning the marked difference in structure and anomalous change in crustal thickness noted in progressing from the High Plains into the Rocky Mountains. Shot points were located this year at intermediate sites in order to study the nature of the transition, and measurements were also carried farther east into the cratonic area. These measurements with those already existing in Wisconsin, Pennsylvania, New York and Connecticut now provide a sampling of crustal structure of not only nearly half the continent, but also of several diverse geological and tectonic provinces. It is hoped that it will be possible to complete this program, particularly since an analysis of the gravity data suggests that the thickest crust may well lie in the Black Hills region which is yet to be seismically studied.

In connection with the crystalline rock surface 'basement' map, the Committee is cooperating with the American Association of Petroleum Geologists, not only in compiling and contouring data from deep wells, but also in obtaining geophysical measurements that will give supplementary data where there are few or no wells reaching the crystalline rock surface.

As in previous years the Committee has been able to further the study of the continents by arranging for the loan of equipment to educational or other institutions. Six such loans were arranged this year, and, in addition, specifications and advice on instrumentation were furnished the U. S. Geological Survey for their Project Vela seismic study of the crust. A Geological Survey party also participated in the University of Wisconsin seismic program in order to study field problems as did a party from the Lamont Geological Observatory of Columbia University.

Appendix 12—Progress Report of the Panel on Hydrology to the Federal Council on Science and Technology

W. B. LANGBEIN, *Chairman*
WILLIAM THURSTON, *Secretary*

WILLIAM BENSON
A. L. COCHRAN
O. C. HOPKINS
C. H. WADLEIGH

BACKGROUND

On June 10, 1960, the Standing Committee of the Federal Council on Science and Technology established an *ad hoc* Panel on Hydrology to report on ways of stimulating research in scientific hydrology, as distinguished from the assessment and development of water resources. The Panel, it was noted, was created in response to the interest among

Earth scientists in stimulating work in hydrology.

In beginning its work, the Panel reviewed the efforts to establish a discipline of scientific hydrology. Surveys of the field of water resources investigations have been conducted many times during the past 25 years, and the needs and opportunities for basic research in hydrology have been identified repeatedly. Although scientists in the geological and geophysical disciplines have recognized and discussed the scientific basis of hydrology, and several organizations have given thought to courses that might be followed in promoting fundamental studies in hydrology, little action has been taken, apart from that related to water resources development. A great many committees and panels have been dealing with regional coordination, interstate river compacts, interagency operations, water control and management, legal aspects, and technical procedures and standards, but none of these has been so organized as to focus its attention on scientific hydrology.

Hydrology as a Science

One of the first obligations imposed on the Panel by the Standing Committee was to define the field of hydrology. Efforts to define hydrology as a science, as distinguished from the application of science-in-general to problems of water assessment and management, must take into account the long-standing views against as well as for 'hydrology' being a distinct discipline within the Earth sciences.

Definition

Hydrology is the science that treats of the waters of the Earth, their occurrence, circulation, and distribution, their chemical and physical properties, and their reactions with their environment, including their relation to living things. The domain of hydrology, therefore, embraces the full life history of water on the Earth.

Commentary

Hydrology is the examination of the whole continuum of the water cycle conceived as a circle made up of numerous arcs some of which traverse the domains of other related Earth sciences. As an interdisciplinary science, hydrology involves an integration of other earth sciences to the extent that these help to explain life history of water, and its chemical, physical, and biological constituents.

Arcs of the water circle transect the domain of man's existence—the Earth's biosphere. Human history is closely linked with water. Life was born in Precambrian seas. Civilization arose in the ancient 'hydraulic communities' of Africa and Asia. Today water is still an essential ingredient of the industrial and economic might of nations, great and small. The critical importance of water to modern civilization provides a two-pronged reason for the study of hydrology; it is a base for sound economic development, and for explaining the nature of man's existence and improving his way of life through the years ahead.

Six major arcs of the hydrologic cycle may be described as follows:

I. Atmospheric transport and precipitation: This arc of the circle traverses the domain of meteorology, yet accumulation and precipitation of moisture from the atmosphere are key parts of the hydrologic cycle. The study of precipitation patterns and the extent of storms and droughts, is a major part of hydrologic inquiry. These inquiries include mapping of rain and snow; the analysis of the depth, area, intensity and frequency of rain storms; and analysis of shifts and trends in climatic patterns.

II. Vaporization: Solar energy, which pulls water back from the oceans and land into the atmosphere, varies in intensity from place to place and from time to time, but it operates at all times on all water within reach. Water evaporates from the oceans, lakes, reservoirs, streams, swamps, vegetation, and moist earth. The evaporation rate is controlled by net solar energy, by capacity of the atmosphere to carry away evaporated moisture, and by availability of water.

Evaporation has prior call on all water precipitated from the atmosphere. Water may evaporate as soon as it hits the ground, as in the dry deserts, where potential evaporation far exceeds the amount of moisture available; it may be transpired by vegetation, whose deeply penetrating roots translate solar energy into force below the land surface; it may sublimate slowly from snowbanks or ice fields at temperatures far below freezing. Only the part of precipitation that escapes evaporation, because of timing or sheer excess, recharges ground water or enters rivers and lakes. In the water budget, whether for a catchment area, a continent, or the entire Earth, the amount evaporated must never be neglected.

III. Infiltration and runoff: This phase of the hydrologic cycle pertains to the phenomena that occur when meteoric water is intercepted by the surface of the Earth. A drop of water which falls on the land surface either enters the ground or runs off. On entering the soil it recharges soil moisture, which may evaporate, be transpired by vegetation, or penetrate more deeply and recharge ground water. Ground water, in turn, eventually drains slowly into surface streams. Water that does not penetrate the Earth's surface runs off directly to the streams.

Hydrology includes study of these processes at the surface of the Earth, and the disposition of the amounts of water that infiltrate below the surface to replenish soil moisture, recharge ground water, and to sustain the flow of streams. The part of the Earth's store of water that passes through this phase of the hydrologic cycle sustains plant life. This arc of the water circle transects the domain of the soil and plant scientists and of the geologist, but explanation and measurement of the accumulation and movement of water is a responsibility of the hydrologist.

IV. Land accumulation and transport of water to storage and evaporative areas: Accumulation and flow of water in saturated zones of the Earth's

crust, upon the Earth's surface in glaciers, ice fields, snow and permafrost, and the discharge of water in surface streams toward the oceans and closed inland seas, constitute an arc of the water circle that has vital importance to man. Water for domestic use, for industry, for power, and for the transport of wastes is obtained from that small part of the Earth's supply of water which is temporarily stored within the rocks or is flowing rapidly in rivers toward the oceans. The amounts of water in the ground or flowing in the streams are thus urgent objects of hydrologic inquiry, and constitute a phase of the hydrologic cycle that has been the exclusive domain of water engineers and geologists. Measurements of water levels in the ground, investigations of porosity and permeability of rocks, and observations of fluctuations in river discharge demand continual attention because sound information on this arc of the water circle is the basis for prudent planning and design of projects for control and use of water.

V. The oceans: The source and sink for the circulation of water on the Earth are the oceans, which contain 97 per cent of all water on the earth. This arc of the water circle traverses the domain of oceanography, but all those aspects of the oceans that affect the circulation of water on the Earth are included in hydrology, and especially the direct effects of the oceans on continental waters in estuaries and in aquifers.

VI. Water as a transport agent: In several of the areas composing the hydrologic cycle, water acts as a geologic agent in weathering and eroding rocks, in shaping the landscape, and as a vehicle for the transport of dissolved salts and the products of erosion. Rivers are shaped by the quantities of water and sediment they transport. The study of these actions and effects of water is within a domain of hydrology that is shared with soil science, geology, and geochemistry.

Hydrology in Relation to Man

All aspects of the many phenomena that affect circulation and origin of water on the Earth are included in the science of hydrology. Hydrology, a unifying function, is critically important to man because disturbance of one part of the circulation pattern affects other parts. For example, pumping of ground water in time affects the flow of rivers, and construction of reservoirs affects vapor exchange with the atmosphere.

Thus, man is a hydrologic agent. By his works he alters the natural circulation of water. He tills the soil, irrigates crops, clears forests, pumps ground water, builds dams on rivers and dumps his wastes into them, and does a host of other useful or wasteful things that affect the circulation and quality of water in nature. Evaluation of these effects is within the domain of hydrology, and so also is the determination of water supplies and the forecasting of effects of man's use upon the water cycle. Burgeoning population and industry make the study of hydrology of critical importance to modern society.

Hydrology as a Fundamental Discipline

In opposing the recognition of hydrology as a fundamental discipline, the opinion is often expressed that hydrology has no field of activity that is separable from practical applications—that hydrology is necessarily a by-product of geology, meteorology, soil science, or engineering, depending on the investigator's approach to problems of water, and represents merely an application of these sciences to water problems. The United States Civil Service Commission does not recognize 'hydrologist' as a classification; 'hydrology' is only an option under other classifications. No school offers a major curriculum in hydrology, nor does any unversity grant a degree based specifically on hydrology.

In rebuttal, it is pointed out that every recognized science had its roots in practical problems and gradually developed an intellectual basis; that from empirical solutions it moved to understanding, theory, and prediction. Such a history for mathematics goes back several thousand years, according to some historians, to the geometry of Egyptian land surveys; for physics and chemistry only a few centuries are involved, and wide recognition of the fundamental bases for oceanography and meteorology goes back only a few years to a few tens of years.

In favoring the recognition of hydrology as a fundamental discipline, it should be noted at the outset that, heretofore, the term 'hydrology' has been used to cover a wide range of scientific and engineering studies and operations dealing with water. The panel mission concerns what one member referred to as 'scientific hydrology.' The arguments in favor of defining 'scientific hydrology' as a separate field revolve around the view that it has fundamental problems that are distinct from the local occurrences and the handling of water, and that the problems are susceptible to abstraction, experimentation, and theoretical treatment apart from operational considerations. 'Scientific hydrology' is similar to meteorology insofar as it is interdisciplinary, a derivative from several physical sciences. The definition should, if possible, take into account the application of the principles of mathematics, physics and chemistry to an understanding of the properties of water in its geological-geophysical environment. The interrelations of biology and hydrology were discussed briefly, but a firm argument was not developed.

These discussions within the Panel brought out clearly that hydrology is an individual discipline, even though it cannot be separated sharply from other Earth sciences, such as meteorology and from oceanography, for all of them bear on each other. The definition of hydrology would have to take into account the need to study the continuum of the water cycle, and therefore to be all inclusive in one sense, without attempting to expropriate the entire fields of meteorology and oceanography in another sense. As in the case of other interdisciplinary fields, hydrology seeks to make a deliberate and intelligent synthesis of many over-

lapping sciences. A definition might appear as a simple but sweeping statement; the commentary accompanying the definition clarifies hydrology as the study of the life history of water, including the chemical, physical and biological constituents that are essential to the history. No other science is, strictly speaking, interested in the full life history of water.

Education in Hydrology

The Panel noted that the deficiencies in hydrologic research may be linked to the deficiencies in formal training facilities in hydrology as we defined it. Most scientists who are engaged in hydrologic inquiry had their basic training in one of several disciplines, such as geology, hydraulic engineering, or silviculture; they acquired competence in hydrology through employment on rather limited phases of the field. The study of hydrology, however, requires insight into the many aspects of the history and circulation of water on the Earth. Therefore, broad training in hydrology as an Earth science is needed, as well as greater interest in hydrologic instruction and research among the universities so that they may take a large part in introducing new mathematical tools and challenging theories to hydrology. The Panel has enlisted the aid of Professors A. T. Lenz and M. G. Wolman to report on this matter.

International Cooperation in Hydrology

As a means of enlarging the scope of hydrologic inquiry and of focusing the attention of other geophysicists on hydrologic phenomena, the Panel is making a study of the possibilities of an international program of hydrologic research. The occurrence of water in the United States is but a consequence and part of the circulation of water on the Earth as a whole. Nevertheless, most hydrologic inquiry in this country, as elsewhere, has been provincial. Little is known of the movement of water from the continents to the oceans, of the atmospheric transport of water from the oceans to the continents, or of the salts and sediments transported by the circulation of water. It is believed that study of water in the planet Earth can become the means for broadening the base of hydrologic research. Dr. R. L. Nace is assisting the Panel in making a study of the practicability of such a program of research.

The Panel's findings are to be presented to the Federal Council and, through that body, to the President's Scientific Advisor. The program of the Panel has yet to be developed further; comments and suggestions for accomplishing its objectives are invited.

Appendix 13—Recommendation for a Committee on Geophysical Data

Prepared by Woodrow C. Jacobs

The requirement for specific observational and derived data concerning the natural environment for the support of our geophysical research and development programs has assumed proportions of a magnitude sufficient to be of considerable concern to the total United States civilian and military scientific effort. At the present time no single national agency is responsible for the collection, consolidation, and storage of basic observational, experimental, and derived data concerning the natural environment in the broad sense. On the contrary, such technical information is currently maintained in a great variety of data and information centers, which are largely uncoordinated in their activities and—what is more important—are also uncoordinated in their responsibilities and authorities.

A number of recent reports—such as the report of the President's Science Advisory Committee, 'Strengthening American Science,' and the report of the Committee on Science and Astronautics, U. S. House of Representatives, 'Dissemination of Scientific Information,'—have dealt with the broad problems of coordination and dissemination of publications and reports that present the results of scientific research. None of these reports has dealt specifically with the problem of collection and dissemination of the basic data, which are the raw materials of science and technology.

The meteorological services of the United States have acquired years of experience in the matter of collecting, processing, and disseminating basic meteorological data; these services are well aware of the problems associated with this type of activity. Under U. S. Weather Bureau auspices, the services jointly maintain a centralized meteorological data depository at Asheville, North Carolina; this data center is equipped with modern electronic computing devices, and approximately 500 civilians are employed at the site in the collection, storage, processing, and dissemination activities. Nevertheless, it should be recognized that the creation of a meteorological data center of this magnitude has been possible only because the national and international exchange and collection of such data has been a centralized and well-organized governmental activity for nearly a century. The fact remains, however, that except for the recent effort expended under the IGY, there has existed no formal assembling of environmental data comparable to that performed in the meteorological field. The creation of such a central facility does not appear feasible

under the present alignment of agency responsibilities, authorities, and activities, unless some sort of national integrating facility is created that is capable of extending its activities across confining agency lines.

To the extent that the solution to the problem will cross broad departmental and agency lines as well as those of private enterprise, it would appear to fall within the purview of the American Geophysical Union to make appropriate recommendations and, perhaps, to assist in their implementation.

Therefore it is specifically recommended that the American Geophysical Union consider the establishment of a working committee under a full-time chairman for the purpose of investigating the geophysical data problem and of preparing a proposal for action. It is suggested that the NSF be approached for funds necessary to carry out this activity.

Geophysical Society of Hawaii

The Geophysical Society of Hawaii held a meeting November 3, 1960, in the Agricultural Engineering Building of the University of Hawaii, at which Dr. Joseph Smagorinski of the U. S. Weather Bureau, Washington, D. C., spoke on 'Studies of the general circulation of the atmosphere, by use of the electronic computers'.

The Society met jointly with the Hawaii Institute of Geophysics and the Society of Sigma Xi on Thursday December 15, 1960, at the University of Hawaii. Bernard Haurwitz, Professor of Astrogeophysics, and Director of the High Altitude Observatory at the University of Colorado, spoke on 'Atmospheric Tides'.

At a meeting of the Society held on January 12, Dr. Bessel D. van't Woudt, Assistant Professor of Agriculture at the University of Hawaii, spoke on problems of the development and utilization of water for irrigation.

New York Meeting of AAAS

In connection with the annual meeting of the American Association for the Advancement of Science in New York, the AGU held a single session on December 28, 1960, on the subject 'The Impact of Space Research on the Sciences.' Three papers were given as follows: Gordon J. F. MacDonald, 'The Interaction between the Earth Sciences and Planetary Studies;' Philip H. Abelson, 'Planetary Environments and Extra-Terrestrial Life;' and Martin Schwarzschild, 'Flying Telescopes.' About 350 attended this session. Also, the AGU took formal part in the arranging of a two-day symposium held December 26–27, relating to our knowledge of science on the Chinese Mainland; this consisted of 25 papers, geophysics having been covered by J. Tuzo Wilson with relation to the solid Earth, and by Malcolm Rigby with respect to meteorology, hydrology, and oceanography. On December 29 AGU sponsored certain sessions relating to the Earth sciences, including the showing of some of the films produced in connection with the IGY effort. On the same day, the AGU took part in the sponsorship of a panel discussion on the planet Earth, arranged by the National Science Teachers Association. The AGU also cosponsored a symposium on December 30 entitled 'The Mohole,' which consisted of six papers.

Special Announcements

• TWENTY-THIRD BOWIE MEDALIST NAMED—Keith Bullen, Professor in the Department of Applied Mathematics, University of Sidney, New South Wales, has been named the Twenty-Third William Bowie Medalist. The award will be made at the Forty-Second Annual Meeting of AGU in Washington, D. C., in April.

• FORTY-SECOND ANNUAL MEETING TO BE HELD IN WASHINGTON, D. C., APRIL 18–21, 1961—This notice is a reminder that the Forty-Second Annual Meeting of AGU will be held in Washington, D. C., April 18–21 (inclusive), 1961. First technical papers will be presented in the morning of April 18, and the technical programs will continue through the afternoon of April 21. The 'Smoker' is scheduled for Wednesday evening April 19; the Award of the William Bowie Medal, and a banquet, are scheduled for Thursday evening, April 20. Please note that the meeting precedes the meetings of the National Academy of Sciences, which are scheduled for the following week.

General information relating to the programs appeared in the December, 1960, issue of *Transactions*, pp. 683–684. Programs will be mailed to all members about March 15. Note also that in addition to the programs scheduled by the various Sections of AGU, a special symposium on the planetary sciences has been arranged.

Information regarding accommodation for lodgings was given in the December issue of *Transactions*, p. 683; it is usually possible, also, to secure accommodations through the Housing Committee of the Washington Board of Trade, 1616 K St., N. W., Washington (REpublic 7-2600 or STerling 3-3535), or to be directed by it to available lodgings.

• FIRST NATIONAL WESTERN MEETING TO BE HELD DECEMBER 27–29, 1961—The First National Western Meeting of the AGU is scheduled to be held at the University of California at Los Angeles on December 27, 28 and 29, 1961. Joseph Kaplan, UCLA, is the Chairman, and William W. Kellogg, 14,739 McKendree Ave., Pacific Palisades, Calif.,

is the Secretary of the Committee for this meeting.

● OFFICERS OF AGU ELECTED FOR NEXT TRIENNIUM—The following officers were elected for the triennium July 1, 1961 to June 30, 1964:

Officers of the Union

President	THOMAS F. MALONE
Vice President	GEORGE P. WOOLLARD
General Secretary	A. NELSON SAYRE

Section of Geodesy

President	FLOYD W. HOUGH
Vice President	CHARLES A. WHITTEN
Secretary	BUFORD K. MEADE

Seismology

President	JAMES A. PEOPLES, JR.
Vice President	JACK E. OLIVER
Secretary	BENJAMIN F. HOWELL, JR.

Meteorology

President	MORRIS NEIBURGER
Vice President	HENRY G. HOUGHTON
Secretary	WOODROW C. JACOBS

Geomagnetism and Aeronomy

President	C. T. ELVEY
Vice President	E. H. VESTINE
Secretary	J. H. NELSON

Oceanography

President	DONALD W. PRITCHARD
Vice President	ROBERT S. ARTHUR
Secretary	ARTHUR E. MAXWELL

Volcanology, Geochemistry, and Petrology

President	HATTEN S. YODER, JR.
Vice President	EDWARD D. GOLDBERG
Secretary	DAVID R. WONES

Hydrology

President	WILLIAM C. ACKERMANN
Vice President	DAVID K. TODD
Secretary	RALPH N. WILSON

Tectonophysics

President	LOUIS B. SLICHTER
Vice President	DAVID T. GRIGGS
Secretary	IRIS BORG
Executive Committee	GEORGE A. THOMPSON PATRICK M. HURLEY

The following representatives to the Committee of the Pacific Southwest Region were elected: *Meteorology*—W. D. Duthie, Robert E. Holzer, Morris Neiburger; *Geomagnetism and Aeronomy*—E. H. Vestine; *Oceanography*—Charles S. Cox, Jacob B. Wickham; *Hydrology*—Arthur F. Pillsbury, Joseph F. Poland, David K. Todd.

The following representatives to the Committee of the Pacific Northwest Region were elected: *Geodesy*—Fred Natella; *Seismology and Tectonophysics*—Robert de Luccia; *Meteorology*—Robert Beaumont, Fred Decker; *Geomagnetism and Aeronomy*, and *Volcanology, Geochemistry and Petrology*—Keith E. Anderson; *Oceanography*—Robert Paquette; *Hydrology*—Charles L. Barker, Hollis Orem, Meredith Thoms.

● INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS SYMPOSIA DURING 1961—Advice has been received (January 1961) from the IUGG headquarters, 140 rue de Grenelle, Paris 7e, France, that the following symposia have been planned for the year 1961.

International Association of Geodesy: (a) Recent Movements of the Earth's Crust; Moscow, summer 1961 (date not set as of January; organized by National Committee on Geodesy of the USSR), (b) Gravity Reductions; Cambridge, England June 1961.

International Association of Meteorology and Atmospheric Physics: (a) International Cloud Physics Conference; Canberra and Sydney, Australia, September 11–21; sponsored jointly by Australian Academy of Sciences, the Commonwealth Scientific and Industrial Research Organization, and the IAMAP. (b) International Ozone Symposium; Arosa, Switzerland, August 14–19; Dr. H. V. Dütsch, High Altitude Observatory, University of Colorado, Boulder, Colorado, in charge. (c) International Radiation Symposium; Vienna, Austria, August 14–19; in cooperation with World Meteorological Organization. (d) Changes of Climate with Special Reference to the Arid Zones; Rome, Italy, October 2–7; in technical collaboration with UNESCO and World Meteorological Organization.

International Association of Geomagnetism and Aeronomy: International Conference on Cosmic Rays and Earth's Storms; Kyoto, Japan, September 4–15.

International Association of Physical Oceanography: Basic Problems in Turbulence and their Relation to Geophysics; Marseilles, France, September 4–9; in cooperation with IAMAP and International Union of Theoretical and Applied Mechanics.

International Association of Scientific Hydrology: Subterranean Waters; Athens, Greece, September or October; in cooperation with UNESCO Committee on Arid Zones.

International Association of Volcanology: Ignimbrites and Hyaloclastics; Catania, Sicily, September 15–24, (will include field excursions).

In addition, a special meeting of the International Association of Seismology and Physics of the Earth's Interior will be held in July, in Paris, to discuss the future of the International Seismological Summary.

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NATIONAL ACADEMY OF SCIENCES

Number 43 • January 1961

IGY BULLETIN

A monthly survey of programs and findings of the International Geophysical Year and the International Geophysical Cooperation–1959 as related primarily to United States programs. The Bulletin *also reports on international programs in geophysics and space science that have grown out of the IGY, and on their results.*

Meteorological Rockets and Satellites

The following is a summary of a paper by Harry Wexler, Director, Meteorological Research, U. S. Weather Bureau, presented at the Symposium on Space Research, Buenos Aires, Argentina, Nov. 28–Dec. 3, 1960.

The history of meteorology has been punctuated by a number of developments, notable among which have been the persistent efforts of meteorologists to observe ever larger portions of the atmosphere—with the ultimate goal of observing all five billion million tons of it. In recent years there has been marked progress toward this goal.

In exploring the atmosphere vertically, the meteorologist has made successive leaps upward using mountain observatories, manned balloons, kites, unmanned balloons, airplanes, radar, and rockets. He has extended his observing capability horizontally by establishing weather-station networks on land and, to a much less adequate degree, over oceans and polar regions. In recent years, the new technique of sounding the upper air with meteorological rockets has been made more effective by the development in the United States of a network of synoptic rocket-sounding stations, and now, for the first time, the meteorologist has access to an observing platform commensurate with the global scale of the atmosphere—the earth-orbiting satellite.

Rockets

Even before data from light-weight meteorological rockets became available, meteorological sounding balloons penetrating above the 25-kilometer level occasionally showed large temperature increases and changes in wind patterns during the winter at higher latitudes in the northern hemisphere. This "explosive warming," first noticed in February 1952 over Berlin, Germany, has since been observed in many areas of the northern hemisphere, particularly in the vicinity of northeast Canada during January and February. IGY meteorological rockets launched at Fort Churchill, Canada, to much greater heights than those reached by meteorological balloons showed that during such periods of explosive warming, winter temperatures in some air layers above 30 km rose to values higher than those observed in midsummer, while wind patterns changed from mostly zonal (east or west) to meridional (north or south).

(Figure 1 is a time section showing changes in temperature and in wind speed and direction above Fort Churchill for the month of August 1957. The figure indicates how rocket data helps fill in the picture for the region above 30 km. *Bulletin No. 40* contains a fuller report on rocket-grenade studies at Fort Churchill.)

This explosive warming, found nearly every year somewhere in the northern polar regions, is not observed to such a marked extent in the southern polar regions. Four years of observation at the IGY Amundsen-Scott South Pole Station reveals only one slight warming, of about 10°C in 24 hours,

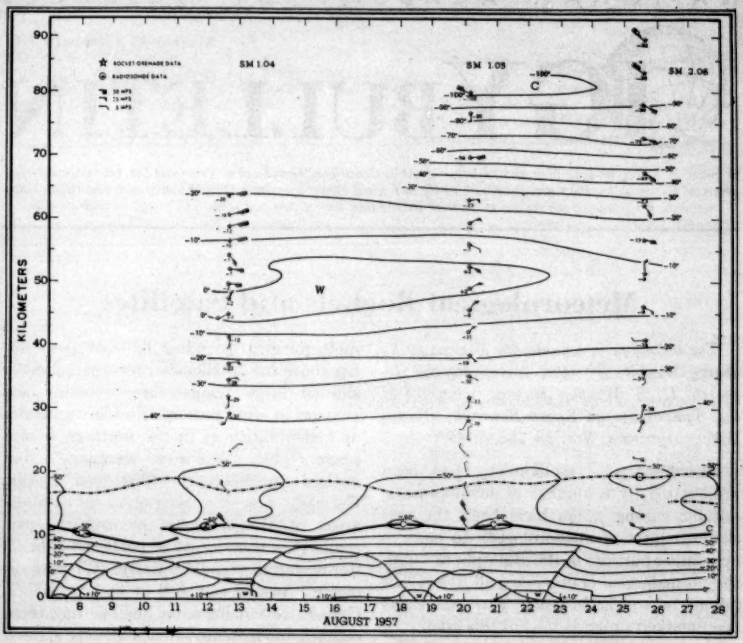

Fig. 1. *Time Section to a Height of 90 Kilometers above Fort Churchill, Canada, August 8–28, 1957. Wind and temperature data based on radiosonde measurements below 30 km and on rocket measurements above 30 km (temperatures in °C). Fronts shown by dotted lines, tropopause by heavy solid line, and thermal boundary by dash-dot line; C and W indicate cold and warm areas. Barbs representing wind speed are at tail end of wind shafts, which point in direction in which wind is blowing —with north at the top of the diagram and east to the right. (From a report by Sidney Teweles, US Weather Bureau.)*

in June 1960, at a pressure level of 40 millibars (20 km). For each of the four springs, 1957 through 1960, the major warming took place about one month after return of the sun above the horizon. This is in quite marked contrast to the pattern in the northern hemisphere, where the warming occurs most often during the polar night.

The spring warming in the south polar region cannot be attributed entirely to solar radiation since, in 1957 for example, the temperature again decreased after the first marked warming peak was reached (in early November) despite the fact that the sun's elevation was increasing; moreover, even at the summer solstice, the 50-mb temperature was 10°C lower than that observed six weeks earlier. The temperature changes in subsequent springs were not as marked as that in 1957, but still indicated that non-solar influences were important.

A completely satisfactory explanation has not yet been found for this remarkable difference between behavior of the northern and southern polar stratospheres. One possible explanation is that the much larger

west-east continental-oceanic contrast in the northern hemisphere exerts a strong influence on the high stratosphere, causing the intense polar cyclone that forms in the early winter to become perturbed and to split into a number of smaller anticyclonic and cyclonic vortices. The anticyclonic vortices are associated with descending air and the cyclonic vortices with rising air, both effects combining to produce a marked temperature gradient between the two types of vortices. If this geographic explanation is correct, meteorologists may have to revise their estimates as to how high in the atmosphere continental-oceanic influences extend.

Another possible explanation is that there is a feeding-in of extra-terrestrial energy unequally in the two hemispheres. Perhaps the Van Allen radiation belts (see *Bulletin Nos. 30* and *32*), which dip into the auroral zones of both hemispheres, may spill more energy into the northern polar regions than into the southern polar regions. However, the energies involved, estimated to be no more than 10 or 100 ergs/cm^2/sec at 100 km, are much too small to account *directly* for the temperature rises of as much as 45°C in 48 hours observed at 25-30 km. It is possible, of course, that even these slight inputs of energy may "trigger-off" changes in flow and in thermal patterns which themselves may induce larger temperature changes by means of vertical motions, but no satisfactory quantitative model for this type of reasoning has been proposed.

The northern hemisphere studies indicate that there is also a great need for lightweight meteorological rocket observations at high latitudes in the southern hemisphere to determine whether, above the ceiling of meteorological balloons, there may be found during the southern polar night the extreme thermal and wind unrest found in the northern polar regions.

Satellites

As always, when the meteorologist is able to observe the atmosphere in new ways he encounters new things. The more extensive the view the better organized the atmosphere appears to be. Phenomena that appear chaotic and random when seen by limited vision take on an orderliness when observed by satellite that holds promise of improved quantitative analysis and prediction. A meteorological satellite in a polar orbit can survey the earth's entire atmosphere twice a day. With an adequate number of such satellites, it should be possible to keep under continuous surveillance every portion of the atmosphere.

Because of the close association of cloud distribution with cyclones and anticyclones, cloud photography was the first objective of the United States meteorological satellite program. The first television cloud-observing satellite, TIROS I, launched April 1, 1960 (see *Bulletin No. 35*), produced nearly 23,000 pictures of the earth during its 78 days of useful life; more than 60% of these are good-quality cloud photographs, useful in meteorological research. The pictures yielded almost immediately two important findings: spiral cloud patterns with diameters as great as 1000 miles (*Bulletin No. 35*, Fig. 10), and large areas composed of many crescent- or doughnut-shaped cloud cells with diameters of 30 to 50 miles (Fig. 2).

Many of the large spiral cloud patterns have a marked banded structure and are associated with cyclonic storms. No two of these cyclonic cloud patterns are exactly alike. The smaller, 30- to 50-mile-wide, cellular clouds are apparently of convective origin and are too large to be seen by the human eye but too small to be recognized on conventional meteorological charts. These convective cells probably play an important role in transferring heat, water vapor, and momentum from the surface to the lower layers of the atmosphere.

TIROS I photographs also revealed other interesting meteorological and related phenomena, including cloud bands of a tropical cyclone north of New Zealand; cirrus streamers associated with the jet stream over the southern Andes; double-vortex

Fig. 2. *TIROS I Wide-angle Photograph of the Tropical South Pacific Showing "Cloud Streets" Consisting of Large Cumuliform Cloud Masses Representing Large Convective Cells. The clouds are embedded in the easterly tradewinds.*

clouds in cyclones apparently having only one low-pressure center; cumulus cloud "streets" in the tropics (Fig. 2); a single, long, thin cloud about five miles wide and several hundred miles long in the vicinity of the Gulf Stream east of Florida, and its reverse—a long, thin *cloudless* streak imbedded in an otherwise continuous cloud cover near Madagascar; a broken pattern of sea ice in the Gulf of St. Lawrence; and snow fields in the Himalaya Mountains and in the Alps. In addition, a series of photographs obtained from five orbits over the southern Indian Ocean in late April, 1960, enabled construction of a synoptic cloud chart for that area, composed of four main cyclonic centers. One of these storms later moved into southern Australia, giving a prolonged period of precipitation.

The successful TIROS I experiment clearly shows that meteorological satellites must be included as an integral part of a comprehensive world-wide weather observing system. Their ability to give complete global coverage, to look at familiar meteorological phenomena from a new vantage point and to reveal organized motions and processes over a great range of dimensions, will influence virtually all phases of meteorological development and operations.

TIROS II, launched on November 23, 1960, continues the cloud-cover experiment begun with TIROS I and, in addition, carries several infrared radiation sensors to measure the earth's heat balance, temperatures of cloud tops and of the earth's surface, and other properties. TIROS II is described elsewhere in this *Bulletin*.

Geology of the Windmill Islands, Antarctica

The following material is based on a report by Richard Robertson, of the Ohio State University Research Foundation. The original report was published by the Foundation in September, 1959, as USNC-IGY Antarctic Glaciological Data Report No. 2, Part IV, Preliminary Report of the Bedrock Geology of the Windmill Islands.

The Windmill Islands area is the most extensive area of exposed rocks in the coastal region of East Antarctica between the Bunger Hills, 250 miles to the west, and King George V Land, 1000 miles to the east. Capes and islets extend for about 20 miles along the eastern side of Vincennes Bay, where they are exposed at the margin of the continental ice sheet. (See *Bulletin No.* 32, Fig. 7.) Wilkes IGY Station is at 66° 15′ S, 110° 31′ E, at the western tip of Clark Island, near the northern end of the Windmill Islands (see Fig. 3).

Geologic field observations were made in 1958 by Richard Robertson, aided by Caspar Cronk and John Hollin; all were members of the Wilkes Station scientific staff. Geologic mapping was carried out using US Navy Hydrographic Office charts (scale 1:12,000) and other maps prepared in the field; final data were transferred to a topographic map at the scale of 1:50,000. This report is based on hand-specimen identification of the rocks. A detailed petrographic analysis of rocks from the Windmill Islands area is now in progress; the work is supported by the Institute of Polar Studies, Ohio State University.

(*Note: All or most of the rock nomenclature used in this report can be found in standard dictionaries.*)

Physiography

The topography of the Windmill Islands is relatively gentle and is controlled to some extent by the rock types present. Summits of the hills are generally accordant at an elevation of about 250 feet and may represent an old erosion surface. This surface is cut by "*U*"-shaped valleys formed by glacial activity and by broad, deeper valleys which, at present, form arms of the sea. The area below sea level has considerably greater topographic relief than that above. An especially good example of this difference in relief occurs south of the island group, where a 1000-fathom trench extends outward from the Vanderford Glacier; this trench may represent a fjord scoured out earlier by the glacier.

The southern islands are composed of igneous rocks in a stock-like or batholithic intrusion, and the northern islands consist of various metamorphic rocks with a migmatite zone in the region adjacent to the intrusion. (A stock is a body of igneous rock formed at great depth, generally granitoid in texture, and covering up to 40 square miles in surface area; similar but still larger bodies are termed batholiths. Migmatite is a layered or mixed rock of alternating pods or irregular zones of schist and granitic material.)

In general, the topography of the islands to the south is more rugged than that of the islands to the north. The Frazier Islets, however, which are the westernmost of the Windmill Islands and among the most northerly, have high, steep cliffs.

Water from melting snow is present for as much as three months of the year. This water occupies no well-defined bedrock channel but flows through ground moraine in wide, thin sheets. The ground moraine—scattered rock debris deposited from the bottom of melting glaciers—is concentrated in the flat-bottomed valleys. Where the melt water is especially abundant, small lakes form behind dams of permanent ice, moraine material, or sills of bedrock.

Vegetation is limited to mosses, lichens, and colonies of algae, which form thick carpets in moist, wind-sheltered areas. Ani-

mal life is restricted to Adelie penguins, petrels, skuas, a few seal species, and sea elephants.

Rock weathering is promoted largely by the freezing of water in fractures. This frost-wedging process goes on even when the air temperature is considerably below freezing since strong solar radiation warms the rocks sufficiently to cause a film of water to form, some of which seeps into cracks in the rocks and re-freezes. Prominent honeycomb rock surfaces are found on Browning and Peterson Islands. The honeycombing may start at breaks in a hard outer crust formed over deeply weathered rocks. These breaks in the outer crust allow the agents of physical weathering to create hollows in the less resistant material beneath the protective crust. Chemical weathering has penetrated to a depth of 20 inches in the igneous rocks and is elsewhere evidenced by copper and manganese stains, similar to desert varnish.

Rock Types

Five broad groups of igneous and metamorphic rocks are present in the Windmill Islands (see Fig. 3). They are, in order of probable decreasing age: metamorphic rocks —locally migmatites; amphibolite dikes and pods; acidic (more than 66% SiO_2) to intermediate (52 to 66% SiO_2) porphyritic intrusive (containing large crystals in a finer-grained groundmass) igneous rocks; porphyritic foliated granite (with phenocrysts—or larger crystals—in a sub-parallel orientation and consisting of potassium feldspar); and basaltic to gabbroic dikes—tabular bodies of igneous rock intruded across the structure of the bedrock.

The gneiss, schist, and migmatite making up the metamorphic rocks are commonly composed of biotite, feldspar, and quartz. Garnet and magnetite, and locally pyroxene and amphibole, are accessory minerals in the metamorphic rocks. Foliation of these rocks is regular, and crenulations, or small folds, are widely separated everywhere except on Frazier and Chappel Islands, where the gneiss is finely crenulated.

Amphibolite pods cutting across the metamorphic rocks are thought to be altered basaltic dikes, and an intrusive body of amphibolite is exposed on Robinson Ridge, at the margin of the stock, or batholith.

The porphyritic rocks of this massive intrusive body are varied in texture and, in general, they are more coarsely crystalline to the west. The composition ranges from that of granite to that of quartz diorite. Bodies of older rocks included within the stock, or batholite, are not common, but Boffa Islet is made up of a jumbled mass of such inclusions. Ford and Cloyd Islands are composed of foliated porphyritic granite in tabular bodies that may be younger than the surrounding stock.

Dikes of diabase, gabbro, and diorite cutting through all of the older rocks form a sub-parallel system in the Bailey-Mitchell Island area along the crest of an anticlinal (upwarped) fold in the bedrock. Similar dikes also intrude the stock in the Odbert and Browning-Peterson Island area.

Bedrock Structure

Asymmetrical anticlinal and synclinal (downwarped) folds, trending approximately NW-SE, have been identified in the migmatite of the northern islands. (In an asymmetric fold, one limb dips more steeply than the other.) The syncline is north of Clark Island and the anticline is between Bailey and Mitchell Islands. The distance between crests of the two folds is about 10,000 feet and they both plunge toward the SE. (Plunge is the dip of the axis of the fold below the horizontal.) The southernmost limb of the anticlinal fold is truncated by a stock (see profile in Fig. 3).

The general shape of the synclinal fold is probably similar to that of the many smaller folds on Clark Island, just south of it. These small folds are generally parallel, eastward-plunging, and isoclinal (limbs parallel) in most places, but some plunge in both directions. One small fold on Clark Island has an axial fault of small displacement.

The large anticlinal fold between Bailey

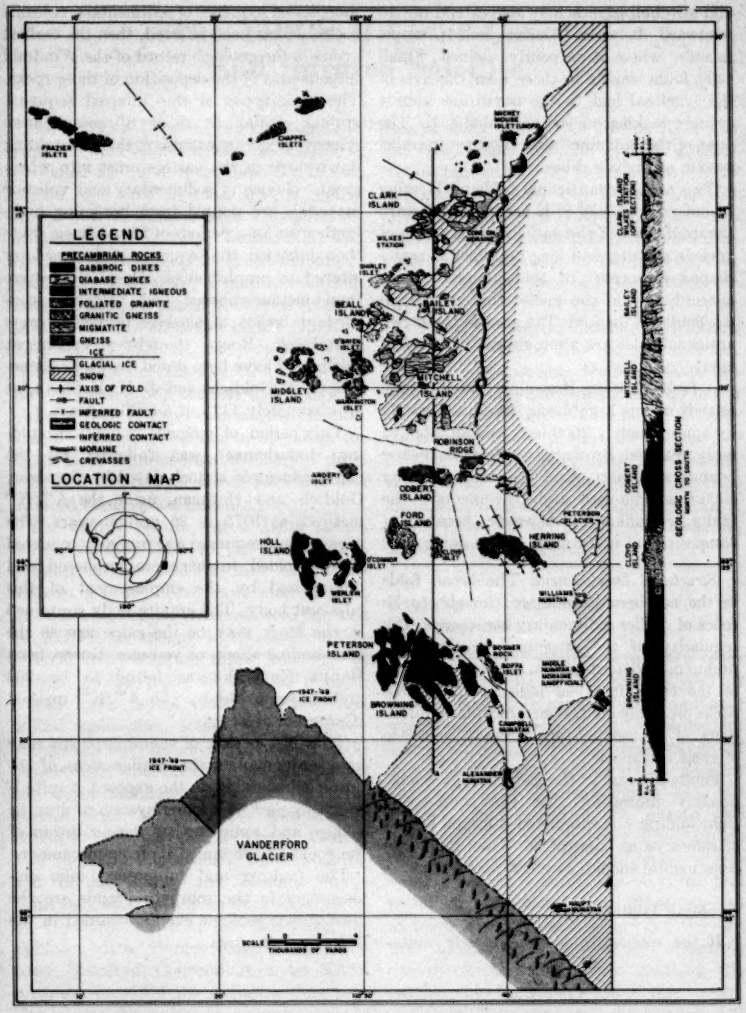

Fig. 3. *Geologic Map of the Windmill Islands. At right is profile along line AA'. (Adapted from map compiled by R. Robertson, drafted by G. A. Van Niel, and based on US Navy Hydrographic Office Map 6889 [1959], corrected by field observations and aerial photographs.)*

and Mitchell Islands may also extend northwestward between Frazier and Chappel Islands, where it is poorly defined. Small tight folds similar to those near the axis of the synclinal fold to the north are almost entirely lacking on the anticlinal fold. The crest of the anticline is cut by a sub-parallel system of diabase dikes.

Two adjacent anticlinal folds on Herring Island trend NNW-SSE and plunge toward the south. One of the anticlines has a core of gneissic granite, and long boudins (sausage-shaped segments) of this material occur concordantly in the gneiss that makes up the flanks of the fold. The axes of these two anticlinal folds are approximately 5000 feet apart.

A fault between Browning and Peterson Islands offsets a gabbroic dike horizontally by approximately 2000 feet, and an inferred fault between Browning and Boffa-Bosner Islands may also offset the same dike by 5000 feet. The vertical displacements of the faults are unknown, however, because of compositional uniformity of the stock.

Structural Development: The broad folds in the northern islands are thought to be relics of earlier sedimentary structures. The regularity of the structural pattern and preliminary determination of the mineralogy of the rocks involved indicate that these rocks probably are the metamorphic equivalents of a sedimentary-volcanic sequence of great thickness.

Faults are rare in the metamorphic rocks, possibly indicating that the small-scale, tight folding was completed during a period of intensive metamorphism when the rocks were mobile enough to allow plastic flow.

Geologic History

If the migmatite is an intensely metamorphosed sequence of sedimentary-volcanic rocks, as has been inferred, then the earliest event in the geologic record of the Windmill Islands area is the deposition of those rocks. The rock types of this inferred sequence appear similar to those of geosynclines. (Geosynclines are extensive, slowly subsiding downwarps in the earth's crust into which great volumes of sedimentary and volcanic materials are poured from bordering highlands over long periods of time.) Basic dikes then intruded the sequence and were later altered to amphibolites. These rocks were then metamorphosed and extensive concordant bodies of alaskite pegmatite were introduced. Rocks thought to represent this period have been dated, by R. L. Cameron, S. S. Goldich, and J. H. Hoffman, at approximately 1115 $\pm$ 5 million years.

This period of orogeny (mountain-building disturbance) was followed by the emplacement of a stock dated by Cameron, Goldich, and Hoffman, using the A^{40}/K^{40} method, at 1075 $\pm$ 25 million years. The geosynclinal sequence was probably rendered plastic, folded, further metamorphosed, and migmatized by the emplacement of this adjacent body. The granite body contained in the stock may be the same age as the surrounding stock, or younger. Gneiss from Haupt Nunatak was found to be 960 million years old by the A^{40}/K^{40} method (Cameron, et al.)

This last period of metamorphism may have accompanied the emplacement of the granitic bodies. If so, the exposed granite is probably part of a larger system of granitic bodies, and some further reconstitution of the rocks accompanied their emplacement.

The faulting and subsequent dike emplacement in the southern islands are the most recent geologic events recorded in the bedrock of the area.

The TIROS II Cloud-Cover and Infrared Satellite

The TIROS II meteorological satellite (1960 Pi) was launched at 6:13 am EST, November 23, 1960, from Cape Canaveral, Florida, and was injected into a nearly circular orbit 13 minutes later. The satellite's primary instrumentation consists of two television cameras, to photograph the earth's cloud cover, and sensors to map solar and infrared, or heat, radiation in various spectral bands. With the exception of the radiation equipment, TIROS II closely resembles the TIROS I satellite, launched on April 1, 1960 (see *Bulletin No. 35*), and like that of TIROS I, the TIROS II experimental instrumentation is expected to remain in operation for about three months from the launch date. ("TIROS" is a contraction of Television and Infrared Observation Satellite.)

The launch vehicle was a Delta rocket similar to that used to put the Echo I communications satellite into orbit (see *Bulletin No. 39*). Five days after launch, the following orbital elements were released for TIROS II: apogee, 453.2 statute miles; perigee, 386.9 statute miles; velocity at apogee, 16,689 mph; velocity at perigee, 16,943 mph; period, 98.37 minutes; and orbital inclination, 48.53°.

Over-all responsibility for the TIROS project rests with the National Aeronautics and Space Administration, and the operational phase is under the direction of NASA's Goddard Space Flight Center. The radiation experiments were designed, and the data storage and telemetry equipment associated with them were constructed, by Goddard, which is also analyzing the radiation data. Barnes Engineering Company, Stamford, Connecticut, under NASA contract, provided the radiation detectors. Except for the radiation experiments, the satellite was designed and constructed by the Astro-Electronics Division of the Radio Corporation of America, Princeton, New Jersey, under contract to NASA. RCA was also responsible for the special ground-station equipment. The Delta launch vehicle was constructed by the Douglas Aircraft Corporation, which also conducted the launch. Other participants in the development and construction of the payload, and in tracking operations, are the same as for TIROS I.

The Meteorological Satellite Laboratory of the US Weather Bureau, under NASA funding, is responsible for analysis of the cloud-cover data and will participate in the processing and analysis of the radiation data. Cooperating in the project are various Department of Defense agencies. The Weather Bureau and the military weather services are attempting to use some of the cloud-cover data for a limited, experimental, operational analysis program.

Experimental Aims and Instrumentation

The TIROS II satellite is part of a long-range United States program designed to develop a satellite capability for providing world-wide meteorological information. Three major aims behind development of meteorological satellites are: (1) to produce observations of the atmosphere over the entire globe, including the oceans and deserts as well as inhabited areas; (2) to provide as completely continuous observations as are scientifically required and technologically possible; and (3) to attempt to learn how the sun's energy is converted into atmospheric motions by measuring variations in solar energy reaching the earth and in the earth's use of this energy.

TIROS I demonstrated the feasibility of meteorological satellites. It transmitted 22,952 cloud-cover photos during its operating lifetime of nearly three months, relaying

to ground stations meteorological information from many regions of the world where weather information had previously been scanty or entirely lacking and providing new information on patterns of atmospheric circulation and on cloud formations. Some results of analyses of TIROS I cloud photographs have already appeared in the literature[2,3,4,5,6,7,10, and 11].

TIROS II continues the cloud-cover experiment of TIROS I using identical wide- and narrow-angle television cameras[1,8,9, and 12] that "look" through the baseplate of the satellite (*Bulletin No. 35*). Power and telemetry equipment associated with this experiment are also similar to those of TIROS I. In addition, both satellites were equipped with infrared horizon sensors to help determine the satellites' attitude in space and with special solar cells to measure the satellites' position with respect to the sun, permitting calculation of the north direction for use in interpreting cloud-cover data.

The major differences between the instrumentation of the two satellites are in the addition of the infrared equipment in TIROS II and of magnetic instrumentation to control the orientation of TIROS II's spin axis. The infrared and magnetic-orientation-control equipment are described below.

Radiation Experiments: TIROS II carries two radiation experiments[8,9,12]. One consists of five radiation detectors, oriented at 45° to the spin axis, which scan through a combination of the satellite's rotation and its movement along the orbit. These detectors measure:

(1) The earth's albedo—the percentage of reflectivity of radiant energy, or light—in the spectral range 0.2-5 microns.

(2) Infrared radiation emitted by the earth and atmosphere combined in the range 7-30+ microns.

(3) Emitted infrared radiation coming through the atmospheric "window" (the portion of the electromagnetic spectrum to which the atmosphere is quite "transparent") in the range 8-12 microns. Measurements in this spectral range should supply information that may permit (a) cloud detection, especially at night and over areas where the TV cameras are not operated; (b) determination of cloud-top temperatures and, accordingly, a rough measure of cloud-top height; and (c) determination of surface temperatures over cloud-free areas.

(4) Radiation from the water-vapor spectral band, 6.3 microns ± 5%. These measurements should show the geographic distribution of the approximate upper margin of water vapor in the atmosphere, which, in some places, may be near the height of the tropopause (about 20,000–50,000 feet above sea level).

(5) Visible radiation in the spectral range 0.5-0.7 microns. This visual channel is intended to provide maps of visible radiation for use in relating the television pictures and the nonvisible-radiation maps.

The second radiation experiment consists of two sensors, one white and the other black, which together measure the heat balance of the portions of the earth's surface and atmosphere viewed by the wide-angle television camera. The white sensor measures heat radiation from the earth while the black sensor measures both visible (reflected solar radiation) and heat radiation.

Data from the radiation experiments are recorded continuously for each orbit on magnetic tape, to be played back over a three-watt, 237.8 mc/sec transmitter on command from one of the ground stations. If not read off after one orbit, the tape automatically starts erasing its previous data as it begins recording during the next orbit. However, the tape always has the last 100 minutes of radiation data stored on it for playback whenever commanded.

Magnetic Orientation Control: A satellite spinning in space can develop a dipole magnetic field similar to that of a small bar magnet as a result of closed current loops in the circuitry and of any magnetic materials

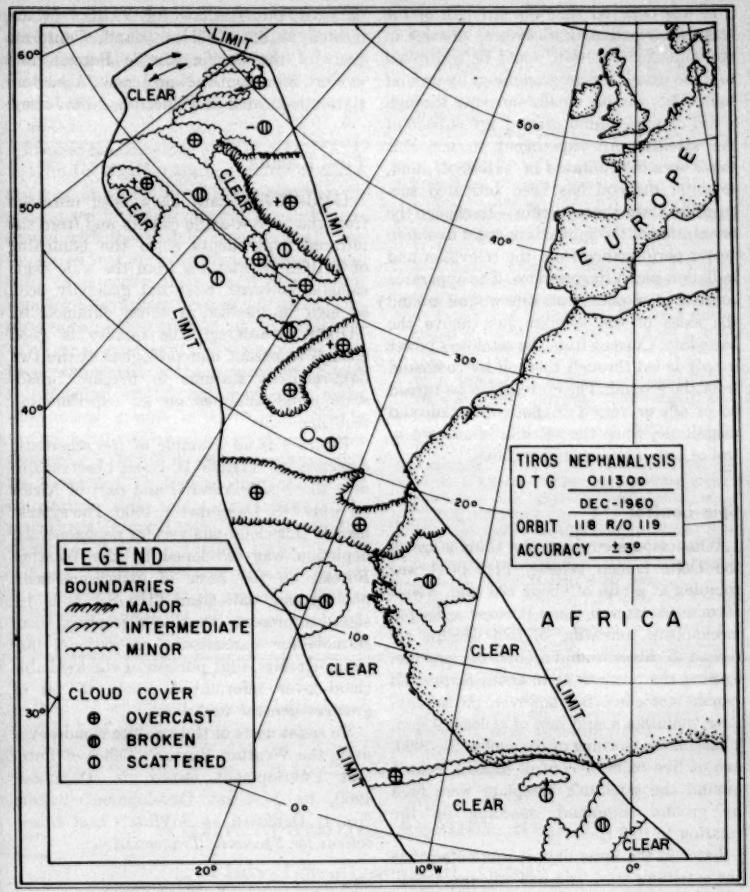

Fig. 4. *Nephanalysis of a Portion of TIROS II's 118th Orbit, on December 1, 1960, Over the North Atlantic and Western Africa. Plus (+) and minus (−) signs indicate relative density of cloud cover; DTG Signifies "Date-Time Group." Arrows represent streaky cloud structure. (From US Weather Bureau.)*

present in the satellite. The magnetic dipole, interacting with the earth's magnetic field as the satellite orbits, produces a torque—or turning force—which slowly changes the direction of the satellite's spin axis in space, thus also changing the direction in which the television cameras are pointing. This effect was discovered in TIROS I.

It was believed that the strength of the magnetic dipole and, therefore, changes in the spin-axis direction, could be controlled to some extent by programming; by ground command, various steady currents through a coil of wire wound around the outside of the satellite. An experiment to test this thesis was incorporated in TIROS II, and, to date, the coil has been activated successfully three times in efforts to change the orientation of the spin axis in order to obtain better performance from the television and radiation-measuring systems. The apparatus consists of an aluminum wire wound around the sides of the satellite just above the baseplate. Current from the satellite's power supply is fed through this coil by command from the ground. The current can be turned on or off, or varied in both direction and magnitude, when the satellite is under control of one of the ground stations.

Spin Control

When separated from the third stage of the Delta launch vehicle, TIROS II was spinning at a rate of about 126 rpm. About 10 minutes later, a timer released a de-spin mechanism, consisting of two weights attached to cables wound around the satellite, slowing the revolutions to about 8 rpm. To remain stable in orbit, however, the satellite must maintain a spin rate of at least 9 rpm. Thus, on the morning of November 25, 1960, one of five pairs of control rockets located around the satellite's baseplate were fired by ground command, speeding up the rotation to 10.8 rpm.

Later in the same day, it was noted that the satellite's spin axis was still precessing, or wobbling, slightly. To compensate for this precession, another pair of spin-up rockets was fired, raising the spin-rate to 13.9 rpm, which appeared to be keeping precession within tolerable limits.

Ground Stations

The two primary ground-command and data-read-out stations for TIROS II are located at San Nicolas Island, California (part of the Pacific Missile Range), and at Fort Monmouth, New Jersey. A backup station is located at Princeton, New Jersey.

First Results

Good-quality data have been obtained from the narrow-angle camera and from the infrared experiments since the launching of TIROS II. Pictures from the wide-angle camera, however, have not generally been as high in quality as those obtained by TIROS I, although the quality is good enough to permit meteorologists at the two data-read-out stations to prepare broad-scale cloud analyses on an experimental, real-time basis.

Figure 4 is an example of the schematic depiction of TIROS II cloud observations over the North Atlantic and part of Africa on orbit 118, December 1, 1960. The system used in this cloud-analysis (or nephanalysis) depiction was developed by the Weather Bureau on the basis of experience with photographic data from TIROS I. It is designed to present, in a simple graphical form suitable for transmission on national facsimile circuits, that portion of the available cloud-cover information likely to be of greatest general usefulness.

To assist users of the satellite cloud-cover data, the Weather Bureau's Office of Forecast Development issued, in December 1960, its Forecast Development Report No. 1, *Depiction of Satellite Cloud Observations for Facsimile Transmission.*

Participation by Other Countries

Immediately after the launching of TIROS II, the Space Science Board (SSB) of the US National Academy of Sciences sent to the Committee on Space Research (COSPAR), in The Hague, a telegram giving orbital and instrumental details of the satellite for transmittal to all COSPAR

participants. Data obtained by TIROS II will be deposited in the World Data Center A meteorological subcenter, at Asheville, North Carolina. When copies are available, notification will be sent to participants through COSPAR.

Prior to the launching of TIROS II, NASA and the US Weather Bureau invited weather agencies in a number of other countries to participate in meteorological research connected with the TIROS experiment. It was suggested that such weather agencies might wish to intensify their standard meteorological observations or conduct special observations during passes of the satellite.

Weather agencies of several countries have been taking part in the experiment. NASA is providing orbital information to assist cooperating groups in these countries in timing local weather observations. After processing, TIROS cloud-cover photos will be forwarded to foreign participants for comparison with their supplementary observations; infrared data will also be forwarded to these participants.

Note: The US Weather Bureau suggests that, since the wide-angle camera in TIROS II has not performed as well as expected, weather agencies desiring to participate in the TIROS experiment may wish to plan their special programs in conjunction with TIROS III, which is expected to be launched later in 1961.

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World Warning Agency Report

July 1-September 30, 1960

This report is one of a series issued periodically during and following the IGY and IGC-59 periods. The reports summarize, on a quarterly basis, solar-terrestrial activity and related decisions of the World Warning Agency (AGIWARN), which was established as part of the IGY World Days Program. The present report covers the third quarter of 1960. A report on the previous two quarters appeared in *Bulletin No. 41.*

Six major solar flares (classified 3 or 3+ by at least one observatory) were reported to AGIWARN during the third quarter of 1960. Of 12 geomagnetic storms recorded during this interval, World-wide Geophysical Alerts (see *Bulletin No. 23*) were issued for

all except two very minor disturbances on July 3 and August 8. No Advance Alerts were issued by the World Warning Agency in connection with the storm that commenced suddenly on August 16 or for the brief disturbance on September 2. All other storms were announced with Advance Alerts as soon as they were recognized as actual disturbances.

As in the last quarter, the magnetic disturbances were divided almost equally between the sudden-commencement type and the gradual-commencement type. Such a division is to be expected during a post-maximum phase of the sunspot cycle, as is now under way. This characteristic mixture of storm types, however, makes accurate forecasting extremely difficult.

Disturbed radio conditions lasting through a whole day were associated with six of the geomagnetic storms recorded, and the North Atlantic Radio Warning Service (NARWS) gave advance warning of three of these, including the most severe storm of the quarter, which began on September 4. All together, NARWS predicted four storms in advance—three on the basis of prior observation of "event-type" solar activity (i.e., having well-defined, observable beginnings and endings, and of short duration) and the other on the basis of the tendency of some solar-terrestrial phenomena to recur at 27-day intervals corresponding to the rotation period of the sun.

As recurrent patterns of solar-terrestrial activity become more clearly defined with the approach of the solar minimum, and if the large majority of geomagnetic storms fall within these patterns, as is usually the case, forecasts will again become more certain. AGIWARN notes that until that time in the present cycle, however, solar observatories have the opportunity of discovering new event-type sun-earth relationships and of exploring avenues of theoretical and statistical research that might lead to applicable prediction techniques.

The following is a list of major solar flares, geomagnetic disturbances, World-wide Geophysical Alerts, and Special World Intervals (SWI) for the quarter beginning on July 1 and ending on September 30, 1960:

Jul	3	15xx*	Magnetic storm begins
	6	05xx	Magnetic storm ends
	14	1702	Severe magnetic storm begins
	15	1600	Alert issued**
	17	10xx	Severe magnetic storm ends
	19	04xx	Magnetic storm begins
		1600	Alert issued
	20	04xx	Magnetic storm ends
	29	17xx	Magnetic storm begins
	31	1600	Alert issued
Aug	1	14xx	Magnetic storm ends
	8	13xx	Magnetic storm begins
	9	12xx	Magnetic storm ends
	11	1916	Class 3+ flare, S-SWF†
	14	0534	Class 3 flare; S-SWF
	16	1410	Magnetic storm begins
		1600	Alert issued
			SWI starts††
	18	11xx	Magnetic storm ends
			SWI finishes
	19	1615	Magnetic storm begins
	20	1600	Alert issued
	22	06xx	Magnetic storm ends
	29	0020	Magnetic storm begins
		1600	Alert issued
	30	1600	Alert issued; aurora expected
	31	11xx	Magnetic storm ends
Sep	2	0706	Class 3 flare; S-SWF
		17xx	Magnetic storm begins
		2234	Class 3 flare; S-SWF
	3	0037	Class 3 flare; Slow S-SWF†
		09xx	Magnetic storm ends
		1600	Alert issued
	4	0230	Severe magnetic storm begins
		1600	Alert issued
			SWI starts
	6	13xx	Severe magnetic storm ends
			SWI finishes
	25	0759	Class 3 flare

* "xx" indicates gradual beginning or ending of a disturbance, following the hour indicated, such that the precise moment could not be determined.

** No ending times for Alerts are issued, as was done during the IGY; this is now left to the discretion of individual observatories.

† Symbols for ionospheric effects are defined as follows: S-SWF—sudden short-wave fadeout and gradual recovery; Slow S-SWF—slow short-wave fadeout (taking 5–15 minutes) and gradual recovery.

†† SWI's, when warranted, start at the time the associated Alert is issued; they finish at the end of the day indicated.

A Very Large Recent Solar Flare

M. A. Ellison, Susan M. P. McKenna, and J. H. Reid, of the Dublin Institute for

Advanced Studies, report that the class 3+ flare of June 1, 1960 (see *Bulletin No. 41*), appears to have been one of the largest in recent years. Their report, in the September 10, 1960, issue of *Nature*, is based primarily on an analysis of Hα film records from the Lyot heliograph at the Royal Observatory, Cape of Good Hope; a complete photographic record of the flare at one-minute intervals was obtained under cloudless conditions.

At the time of maximum extent, the June 1 flare occupied an area of 46 square degrees, or 2230 millionths, of the sun's visible hemisphere (1 millionth = 1,170,000 square miles). Thus, this flare was comparable in area to the great flare of July 25, 1946, which covered an area of 2500 millionths of the solar hemisphere and occurred in association with one of the six largest sunspot groups observed between 1874 and 1954. (Data on the flare and sunspot group of July 1946 from M. A. Ellison, 1946 and 1955.)

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Coupling of Air and Ocean Waves

The following material is based on a more complete report by W. L. Donn and W. T. McGuinness, of the Lamont Geological Observatory, Columbia University. The original report appeared in the Journal of Meteorology, *October 1960.*

Examination of sea- and shore-based wave and air-pressure records accumulated during the IGY at stations in the vicinity of New York City indicates that some long-period sea waves result from resonant transfer of energy from atmosphere to ocean. This coupling, involving air waves associated with a frontal disturbance and gravity waves in the ocean moving outward from the shore, produced, in the area studied, long-period sea waves having amplitudes more than 100 times greater than such air-pressure oscillations would be expected to produce under equilibrium conditions.

The investigations described were carried out under the direction of the Lamont Geological Observatory as part of the IGY Oceanographic Island Observatory Program. Lamont supervised the Atlantic Ocean portion of the United States program. Background information on this program is given in *Bulletin Nos. 2, 6,* and *9; Bulletin Nos. 16* and *22* contain some of the earlier results.

Stations and Instrumentation

As part of the IGY Island Observatory Program in the Atlantic, a long-period ocean-wave recorder and a microbarovariograph (a sensitive atmospheric-pressure recorder) were installed on Texas Tower No. 4, at 39° 48′ N, 72° 40′ W, on the continental shelf about 80 miles southeast of New York City (see Fig. 1). (Texas Tower No. 4 was destroyed in a severe storm on January 15, 1961.) The microbarovariograph, which responds to the rate of change of atmospheric pressure, was located in a shelter on the tower platform, about 90 feet above the water. (*Bulletin No. 9* contains a description of the instrument.) The pressure-sensitive wave recorder con-

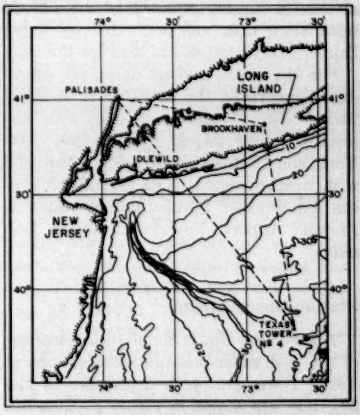

FIG. 1. *Region of Study of Air-Ocean Wave Coupling. Water depths shown in fathoms.*

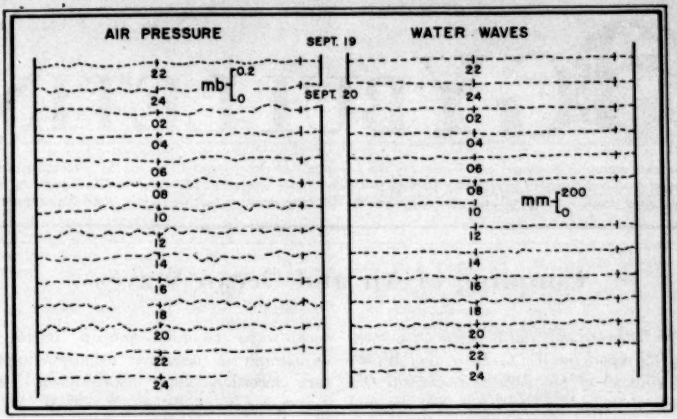

FIG. 2. *Records of Air and Water Pressure from Texas Tower No. 4 for the Period 2200 EST September 19—2400 EST September 20, 1958.*

sisted of an underwater pressure head secured to a vertical cable at a depth of 30 feet, and a sheltered amplifier and recorder.

The instruments were installed and maintained on the Texas tower through the cooperation of the 4604th Support Squadron of the US Air Force. Much of the difficult installation task was performed by Roger Zaunere, David Owen, and Rudolph Romano.

For the investigations described below, data recorded by the instruments on Texas Tower No. 4 were compared with air-pressure observations at Palisades, New York, and at Brookhaven, Long Island, and with weather records from several offices of the US Weather Bureau, notably those at Idlewild Airport, New York, and on Bermuda.

Station Observations

Texas Tower No. 4: Simultaneous tracings of air- and water-pressure records taken at Texas Tower No. 4 on September 19 and 20, 1958, are shown in Figure 2. Each line represents a two-hour period, and absolute time (EST) is labeled every hour. Increasing pressure is shown by an upward movement on both traces; hence, the trace for water waves indicates actual sea-level configuration.

Although simultaneous oscillations can be detected on both air and water records as early as 0200 September 20, this relationship becomes much more distinct between 1400 and 2000, when amplitudes on both records are greatest. During this interval, maximum air-pressure oscillations reached 0.05 millibars (1 mb = 1000 dynes/cm^2, or 1/32 inch Hg; sea-level air pressure = 1.0132×10^6 dynes/cm^2, or 29.92 inches Hg), and ranged from about 0.01 to 0.05 mb. Maximum sea-level oscillations varied from about 15 to 40 mm.

Under conditions of equilibrium, sea-level changes corresponding to the recorded air-pressure variations would reach a maximum of 0.5 mm of water. Actual sea-level changes recorded from 1400–1600 and 1700–1900 hours, however, showed oscillations as much as 115 times greater than the barometric equilibrium waves (Table 1), strongly indicating a dynamic magnification beyond

Table 1. Actual sea-level changes as determined from Texas Tower No. 4 records for 1400–1600 and 1700–1900 hours, September 20, 1958.

Time interval	Mean amplitude of air-oscillations (mm sea water)	Mean amplitude of water oscillations (mm)	Magnification
1400–1600	0.17	13.8	81
1700–1900	0.28	32.2	115

the equilibrium effect. (Note that air pressure is expressed in the table in millimeters of sea water, thus giving directly the mean values of the barometric equilibrium waves in the sea.)

Examination of the records indicates that both the air and water oscillations are slightly dispersive (i.e., wave period decreases with time or velocity). Moreover, Figure 3, a plot of arrival time against wave-crest number for simultaneous air and water waves, clearly shows a similarity between the dispersion in both media.

It seems evident from the data presented above, and particularly from Table 1, that the simple equilibrium barometric effect is not adequate to explain the magnitude of the observed water oscillations. A possible seismic origin for these waves was ruled out

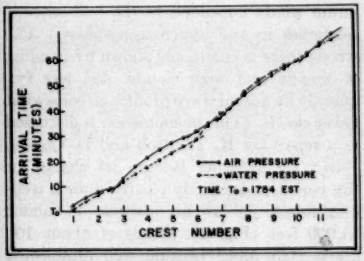

FIG. 3. *Dispersion Curves for Air and Water Oscillations. Wave-crest numbers are plotted against time, which is shown in 10-minute intervals from 1754 EST September 20, 1958. Although dispersion is slight, it is clearly similar in both curves.*

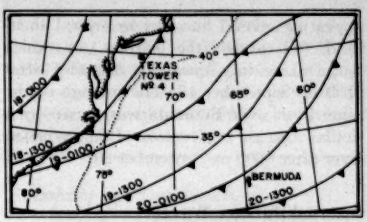

FIG. 4. *Position of Cold Front at 12-hour Intervals between 0100 EST September 18 and 1300 EST September 20, 1958.*

after a detailed study of all earthquake reports for about this time. It thus appears that somewhat special conditions existed, which provided a mechanism for the transfer from air to water of energy well in excess of that of equilibrium conditions.

Palisades, New York: Pressure oscillations similar to those recorded at Texas Tower No. 4 were also recorded on the mainland, at Palisades, during about the same time interval. Although fairly strong oscillations are present in most of the Palisades record, those of short period (about 5 to 10 minutes) became much more prominent from 1000 to 1600 hours, at about the same time as at the tower. In addition, definite continuity of a more gross barometric oscillation was recorded at about 2400 on September 19 by microbarographs at Palisades, Brookhaven, and Texas Tower No. 4. The lack of precise timing on these compressed records does not permit velocity determinations, but this event clearly occurred first at Palisades.

Meteorological Data: It was noted from the meteorological records that a cold front (leading edge of a relatively cold air mass) passed seaward over the area during this time. The approximate positions of this front at 12-hour intervals are shown in Figure 4. As the front moved seaward, its surface was indicated by weather records at Idlewild Airport, near New York City, which show a progressive lifting of the temperature inversion (layer of air, generally

appearing several hundred to several thousand feet above the surface, in which temperature increases with altitude) after 0700 on September 19. The passage of the same front over Bermuda was shown by a similar increase in elevation of the inversion layer after 0800 on September 20.

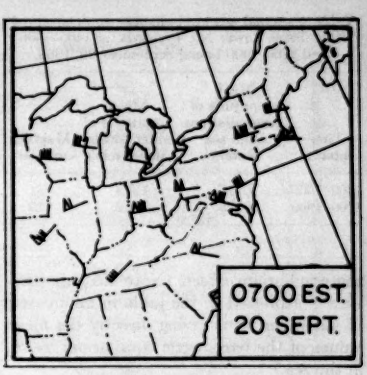

FIG. 5. *Chart of Winds at 35,000-foot Level over the Northeastern United States at 0700 EST September 20, 1958, Indicating Existence of Jet Stream. Arrows appear to fly with the wind; tail barbs represent a wind speed of 10 knots, flags a speed of 50 knots.*

Internal Surface Waves

A detailed investigation involving tripartite detection and orbital wind variations conducted at both Palisades and Brookhaven has established that oscillations of this type are very often waves moving along some meteorological discontinuity within the atmosphere. (P. Milic, in 1956, discussed in detail the criteria for the existence of surface-pressure perturbations; use of these criteria made possible the barometric detection of the internal surface waves observed at Palisades and Brookhaven.) Also, the currently unexplained dispersive nature of these air oscillations is a common feature of surface waves in a layered medium. It thus appears that the atmospheric-pressure oscillations described above were the ground-level manifestations of internal waves probably traveling on the frontal discontinuity.

It is possible to compute the theoretical phase velocity of these internal surface waves on the basis of vertical synoptic data. By using Idlewild radiosonde information, the average height of the inversion layer at 0700 on September 20 was found to be 2000 meters (6560 feet). The temperatures above and below the discontinuity were 283°K (50°F) and 276°K (37.4°F), respectively. Based on the equation for phase velocity of internal waves on an interface within two incompressible fluids, the computed wave velocity relative to the ground is 45 knots, or about 52 mph (E. Gossard, in 1956, obtained similar velocity results by applying this procedure to conditions in Southern California.)

It is suggested that these waves originated in perturbations produced by strong vertical wind shear (variations in wind velocity with altitude) at a much higher level. Very regular pressure oscillations are often recorded by instruments at the Lamont Geological Observatory when the jet stream is present aloft. (The jet stream is a relatively narrow, quasi-horizontal band of maximum winds imbedded in the mid-latitude westerlies in the upper troposphere.) The strong shear is commonly shown by banding of middle and high clouds, and less frequently by actual wave profiles on somewhat lower clouds. (This phenomenon is discussed in a report by K. Tillotson and D. Colson, 1954.) US Weather Bureau jet charts for the period under study clearly show a well-established jet at an altitude of about 35,000 feet (Fig. 5). Winds of about 100 knots (115 mph) became well established in the area of the study toward the latter part of September 20; as shown in Figure 2, the strong 4- to 10-minute air waves also became best developed at this time of maximum vertical shear.

Wave Coupling

The existence of air waves and simultaneous ocean waves having the same period but much greater amplitudes than those of equilibrium barometric waves, strongly suggests the resonant coupling (the coupling of systems having identical wave characteristics) of energy from air to ocean. The evidence also strongly suggests that a dynamic magnification of the water waves occurred. In order to support the theory of resonant coupling, however, it is necessary to show not only a similarity of period, but also of phase velocities of both the air and water waves over a significant fetch—or distance the wind blows over the water in a particular direction.

An average velocity of 40–45 knots for the observed air waves seems reasonable. The possible velocities of long gravity waves in the water are controlled by the depth of water between the coast and the tower. It can be seen from Figure 1 that the slope of the continental shelf from shore to Texas Tower No. 4 is uniform and gentle, with a west-to-east depth profile ranging from 60 to 180 feet. The corresponding range of gravity-wave velocities for these depths is 33 to 46 knots, which well overlaps the possible air-wave velocities. Because of the gentleness of the slope, it seems reasonable to expect resonance between air and water over a fetch of many wave lengths.

Assuming undamped conditions (no loss of wave amplitude or energy with time) in the ocean, consideration of mechanical vibrations shows that the resonant amplitude is a linear function of time, with the range of observed amplitudes requiring about 10 wave lengths for growth. In an analogous experimental study of the coupling of acoustic waves in air to flexural waves in a metal bar, by F. Press and J. Oliver (1954), significant coupling occurred after only 4 wave lengths, and very strong coupling was observed after a fetch of 7 wave lengths.

Summary and Conclusions

Simultaneous air-pressure oscillations and water waves were recorded at the IGY station on Texas Tower No. 4, situated on the continental shelf about 80 miles southeast of New York City, in which the water-wave amplitudes were more than 100 times greater than the possible barometric-equilibrium waves.

The air-pressure oscillations are interpreted as perturbations produced by internal surface waves traveling on a frontal discontinuity. Observed and calculated period spectra for the most prominent and persistent air and water oscillations have peaks at about the same frequencies, between 4 to 10 minutes, and both air and water waves show nearly identical period dispersion. The dynamic magnification of the water waves beyond the equilibrium value, and their similarity to the air waves in spectral distribution and dispersion, indicate resonant coupling between the two media. Such resonant coupling was found to be possible over a significant fetch where the period and phase velocities of air and water waves appear to coincide closely.

It is suggested that, although the water waves are produced directly by resonant coupling to air waves on a frontal discontinuity, the ultimate origin of these water waves may be in the transfer of energy from the high jet stream to the sea surface.

Effects of a Severe Solar Storm on the Orbit of Echo I

The following report is based on material prepared by Robert Jastrow, Chief, Theoretical Division, Goddard Space Flight Center, National Aeronautics and Space Administration, and Robert Bryant, also of Goddard's Theoretical Division.

Recent studies of variations in the orbit of the Echo I satellite (1960 Iota 1) have revealed that on November 12, 1960, at approximately the time of occurrence of a severe storm on the surface of the sun, the atmospheric drag acting on the satellite suddenly increased about twofold, causing a corresponding decrease of two seconds per day in the satellite's orbital period. The drag remained at this high value for several days before returning to its previous level.

Echo I, a passive communications satellite designed to reflect back to earth radio waves beamed at it by powerful transmitters, was launched by NASA on August 12, 1960, into an almost circular orbit with an average altitude of approximately 1000 miles above the earth (see *Bulletin No. 39*).

Solar radiation pressure has caused the satellite's perigee to decrease by about 2½ miles per day, reaching a minimum of about 580 miles on December 28, 1960. In January 1961, perigee was rising again under this influence (as perigee then occurred when the satellite was on the side of the earth opposite the sun) and on January 22 it was 618 miles above the earth. This oscillatory motion will continue until, at a future minimum, atmospheric drag will dominate and the satellite will cease to orbit.

The Solar Storm

The solar storm of November 12 was the most severe since the great flare of February 23, 1956. It consisted of two giant flares on the surface of the sun and several smaller eruptions, all within a period of a few days.

The sun's atmosphere boils and churns at times of unusual solar activity, producing disturbances that are analogous to bad weather on the earth. Thus, solar physicists have begun to refer to this activity as "solar weather." Occasionally, these storms on the sun produce the great eruptions known as flares, which spray charged particles, X-rays, and other kinds of radiation through the solar system.

When the particles and radiation reach the earth they have a number of effects: (1) they increase the number of charged particles in the atmosphere, and this, in turn, weakens and distorts transmission of radio waves through the ionosphere (the November 12 storm blacked out international radio communications for two days); (2) they produce storms in the earth's magnetic field; (3) they produce brilliant auroral displays; and (4) they partially empty and re-fill the Van Allen belts of charged particles trapped in the geomagnetic field, a phenomenon not yet entirely understood.

Figure 6 shows the effects of increased atmospheric drag on the orbit of Echo I as a result of the large solar flares of late November and early December 1960. The greater drag on the satellite, caused by increased atmospheric density along its path, is indicated by corresponding sudden increases in the rate of change of the orbital period.

Cause of Drag Increase

Jastrow and Bryant believe that the most likely cause of the increase in the drag acting on Echo I is an increase in the average density of the air through which the satellite travels. This increase in atmospheric density is produced when particles and

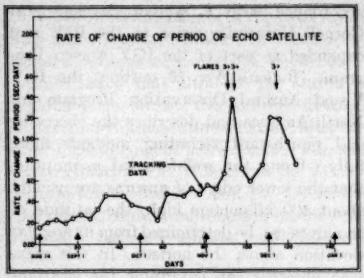

Fig. 6. *Sudden Increases in the Rate of Change of the Orbital Period of Echo I in Late November and Early December, 1960, with the Occurrence of Strong Flare Activity on the Sun.*

radiation from solar flares strike the atmosphere and heat it. The heating results in a slight outward expansion of the atmosphere at lower levels, and, consequently, a great increase in the density of the very thin air at the high altitude at which Echo I travels around the earth.

Previously, scientists at the Smithsonian Astrophysical Observatory at Cambridge, Massachusetts, and in Germany and England, had discovered that the entire upper atmosphere rises and falls, or "breathes," in response to the general level of storminess on the surface of the sun. The response of a satellite to a specific solar flare has been detected only once before, however—in 1959, in the case of Sputnik III. It has not been detected in the orbit of Vanguard I.

Echo I, as did Sputnik III, passes through the outer Van Allen belt, where, according to Explorer VI and VII measurements, the particle intensity increases as much as a thousand-fold after solar flares. Vanguard I, on the other hand, does not go through the outer belt because it is confined to low latitudes, below 33°. It is possible, therefore, that this difference in orbital paths may explain why solar storms have influenced the drag on Sputnik III and Echo I, but not on Vanguard I.

Conclusions

Jastrow and Bryant believe that the detection of this solar-storm effect on the Echo I orbit may provide a clue to the actual mechanism by which solar particles and radiation heat the atmosphere. This is one of the basic problems facing physicists in their effort to understand the influence of solar weather on the earth.

Relationships between Auroras in the Northern and Southern Hemispheres

The following material is based on two reports prepared at IGY World Data Center A, Aurora (Visual), Cornell University, Ithaca, New York, and published as part of IGY General Report Number 12, Report on IGY Visual Auroral Observations, *November 1960. Both of the more-detailed source reports are concerned with comparisons of auroral activity in the Northern and Southern Hemispheres; the first, "Ellsworth Auroral Data—1957," was prepared by R. W. Fillius, C. W. Gartlein, and G. Sprague, and the second, "Some Comparisons between Auroras in the Northern and Southern Hemispheres," by R. W. Fillius. A report on observations at the IGY South Pole Station, by Gartlein, Sprague, and B. Nack, appeared in* Bulletin No. 26.

Visual auroral observations at Ellsworth Station during the IGY period have helped

to determine the physical characteristics and the motions of auroras in southern polar regions, and correlations with similar data from other Antarctic stations have permitted delineation of the southern auroral zone. Comparisons between visual auroral observations in the Antarctic and observations made in North America as part of the US-Canadian IGY Visual Observation Program provide information on the simultaneity of Southern- and Northern-Hemisphere auroras and on similarities or differences in their forms and motions.

In both the Antarctic and in North America, visual observers recorded auroral information on mark-sense IBM cards in accordance with a system developed at Cornell University prior to the IGY and expanded as part of the IGY Aurora Program. (*Bulletin No. 12* outlines the IGY Visual Auroral Observation Program for North America and describes the observing and punch-card recording methods more fully.) Using the well-founded assumption that the lower edges of auroras are usually about 100 kilometers high, the latitude of an aurora can be determined from its angular elevation above the horizon. In this way, each observer can determine the locations of auroras from horizon to horizon over a total latitude range of about 9°, or about 1000 km.

A. Ellsworth Data for 1957

Visual auroral observations made in 1957 at Ellsworth IGY Station (about 78°S, 42°W), Antarctica, as part of the US-IGY program indicate that the number of auroras occurring annually at Ellsworth Station roughly approximates that of the St. Lawrence River area of eastern North America. Comparison of records from Ellsworth with those from the United States shows that on virtually all occasions when an aurora was observed at one of these locations an aurora also occurred at the other; details of their forms, however, appear to be somewhat independent.

Simultaneity of Occurrence in Northern and Southern Hemispheres

The number of days during the austral winter of 1957 on which auroras occurred simultaneously in both hemispheres, and the number of days on which such auroras displayed similar forms, are shown in Table 2. On many days, visibility was so poor that neither the occurrence of an aurora, nor its form, could be ascertained. However, on the basis of hourly reports, more than 99% of the auroras seen occurred simultaneously at both the northern and southern stations. On one occasion only, on July 3, 1957, at 0600 UT, an aurora was reported and photographed in the United States while Ellsworth reported clear conditions with no aurora.

As Table 2 shows, about half the auroras occurring simultaneously in the two hemispheres were similar in forms and in patterns of change of forms, while the other half were not. Among the latter, no common pattern was observable. On some occasions when a glow changed to a homogeneous arc

Table 2. Simultaneity and Similarity of Forms of Northern and Southern Hemisphere Auroras, Austral Winter 1957.

Month	Days With Simultaneous Auroras	Days With Simultaneous and Similar Auroras
June	12	7
July	10	2
August	13	7
September	8	6
Totals	43	22

in North America, Ellsworth reported rayed arcs and pulsating surfaces; on other occasions, conditions were reversed. These observations imply that although the aurora is a global phenomenon, the observed detailed features may be determined locally, after the solar initiating agent has separated into two parts. (*Bulletin No. 12* describes the various auroral forms; *Bulletin Nos. 12, 18, 32, 36,* and others, contain information on the relationships between auroras and solar activity.)

Location of Auroras

Although it is not yet clear just what determines the geographic position of an aurora, an attempt was made to find corresponding geomagnetic latitudes from simultaneous auroral observations in both hemispheres. Times when simultaneous arcs were observed in the two hemispheres were selected, and the latitudes of the Ellsworth observations were plotted against the latitudes of the simultaneous auroras seen at longitude 75°W in North America. The results are shown in Figure 7.

The diagonal line in Figure 7 shows the approximate geographic relation between the northern and southern portions of the aurora. (The size of the circles provides a rough estimate of the precision of determination of the auroras' positions.) If correct, the line indicates that an aurora over Ellsworth station, at latitude 78°S, will be accompanied by a corresponding aurora over Ottawa, Canada, at 46°N.

An aurora over Ottawa tends to curve northeastward and would cross Ellsworth's geographic longitude at Kap Farvel (Cape Farewell) on the southern tip of Greenland. This is presumably near the magnetic conjugate point in the Northern Hemisphere corresponding to the geomagnetic position of Ellsworth Station in the Southern Hemisphere. However, Kap Farvel is at geographic latitude 60°N, which is in twilight from May 1 until mid-August, the interval during which practically all of the observations from Ellsworth are made. Thus, the Northern Hemisphere counterparts of auroras observed in these months at Ellsworth Station cannot be seen at Kap Farvel, and the portion of the auroral zone extending below 50°N in eastern North America is the only region in the Northern Hemisphere from which good simultaneity checks with the Antarctic can be made.

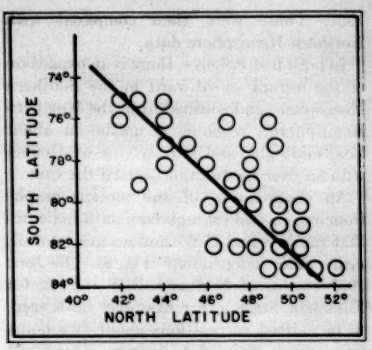

Fig. 7. *Latitudes of Simultaneous Arcs at Ellsworth Station and at 75°W in the Northern Hemisphere, 1957. Diagonal line shows geographic relation between Northern and Southern Hemisphere auroras; circles indicate roughly the precision of position estimates for auroras plotted.*

The locations of the northern and southern halves of the aurora were deduced from the positions of arcs when arcs were reported simultaneously in the two hemispheres. Arcs were chosen solely because they are easiest to identify and to locate.

Auroral Motions

Visual observers report auroral motions as well as the forms present; these motion reports were examined in an effort to identify regular patterns. Plots of north-south and east-west motion in the vicinity of Ellsworth Station were made for the months of May, June, July, and August

1957. These were then compared with Northern Hemisphere data.

In both hemispheres, there is an expansion of the aurora (northward in the Southern Hemisphere and southward in the Northern Hemisphere), reaching a maximum about local midnight, and a daily east-west effect with an excess of motion toward the east.

An examination of the motion graphs from one station for a given month indicates that the N-S and E-W motions are coupled, rather than independent (Fig. 8). The June 1957 curves of N-S and E-W motion for Ellsworth Station, for example, both seem to be shifted to positions about two hours later than those for August. This shift probably results from the particular auroras observed rather than from any systematic seasonal effect, as similar shifts also occur in the May and July records of N-S motion.

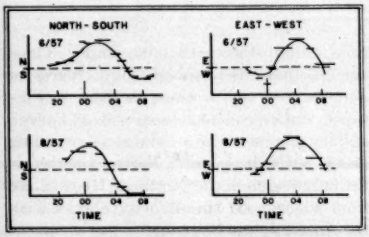

Fig. 8. *Daily Motions of Auroras Seen at Ellsworth Station in June and August 1957. Dashed line represents east-west zenith meridian in N-S graphs, and north-south zenith meridian in E-W graphs; horizontal lines are positions of auroras observed.*

The excess of eastward motion and of northward motion might suggest that they, too, are coupled. However, they are out of phase. Moreover, it seems necessary to ascribe some of the apparent motion to perspective effects, as Ellsworth Station is close enough to the geographic South Pole so that auroras located 50° of longitude (or three time zones) east or west of the station, can be seen. Thus, two observers in this general area whose local clocks were three hours apart might see the same aurora, and the resulting time-motion curves would have significantly different values at the two stations. Some perspective effect is implied, perhaps connected with the local expansion of the aurora that typically occurs about midnight, or with deflection by the earth's magnetic field.

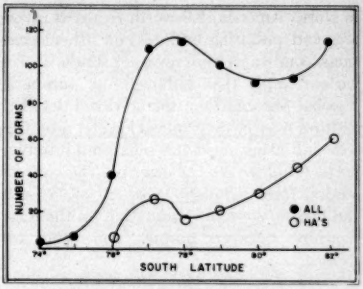

Fig. 9. *Number of Auroral Forms (dots) and Comparative Number of Horizontal Arcs (circles), plotted as a Function of South Geographic Latitude. The data were obtained by selecting reports for the intervals within two minutes of the hour on nights when auroras were visible during the IGY.*

Location of Southern Auroral Zone

The southern auroral zone is defined as the region of the Southern Hemisphere that has the largest number of overhead auroras per year. Ellsworth visual data were analyzed to determine the location of this zone with respect to the station. Figure 9 shows, as a function of geographic latitude, the total number of forms (dots), and the number of arcs (circles), observed within two minutes of the hour. Observations at latitudes 77°, 78°, 79° S are over-weighted by a perspective effect, first noted by C. T. Elvey (1955), and those at the outer limit of the range are less reliable because of ground haze. There is no doubt, however, that the number of forms increases toward the south, and presumably the number of

auroras also increases in this direction from the station. Comparisons with a similar plot of data from the IGY South Pole Station shows that the zone must lie between the South Pole and Ellsworth Station. (See *Bulletin No. 26.*)

The position of the southern auroral zone corresponds to a geomagnetic latitude of about 68°S. The geomagnetic latitude of Ottawa, Canada, which sees the conjugate auroras in the Northern Hemisphere, is 57°N.

A tentative set of isochasms, or lines of constant auroral frequency, is shown in *Bulletin No. 26*, Figure 2. The isochasms are modified, in some manner not yet clarified, by daily and probably seasonal effects, but this modification should amount to less than 10° of latitude.

Summary

The results of IGY visual auroral observations described above may be summarized as follows: (1) An aurora occurs at the same hour in both the Northern and Southern Hemispheres. (2) The various auroral forms, as well as the stages in their development, are not necessarily the same in the northern and southern portions of the aurora. (3) Auroras seen from Ellsworth Station, in the Antarctic, are usually accompanied by a conjugate aurora over the St. Lawrence Valley of Canada. (4) The portion of the aurora seen at Ellsworth Station has its greatest expansion near local midnight. (5) The southern auroral zone passed between Ellsworth Station and the geographic South Pole in mid-1957.

B. Comparison of Northern and Southern Hemisphere Auroras

The aurora is believed to be caused by charged particles coming from the sun and becoming trapped in the earth's magnetic field. The particles are thought to spiral along lines of magnetic force to the northern and southern auroral zones, where some of them enter the atmosphere and collide with air particles, releasing energy in the form of auroral displays. If this theory is correct, corresponding auroras should occur at magnetic conjugate points—the points at the two ends of a line of force. Also, the extent of the aurora would be determined by the radius of gyration of the particles, and this gyration radius would, in turn, be determined by the particle velocity and angle to the line of magnetic force. Thus, variations might be expected between the auroral zones, and within each zone, as the earth's angular relationship to the sun changes daily and seasonally.

The following material presents the results of direct comparisons between North American auroral maps and reports from Ellsworth Station. Ellsworth Station is especially well situated for such comparisons.

Simultaneous Occurrences

Simultaneity comparisons can be made only when the observing regions in both hemispheres are in darkness. In the vicinity of Ellsworth Station, at the geographic latitude of 78°S, darkness falls during portions of days between the months of March and October, and night is continuous from May to mid-August. Gartlein, Nack, and Sprague (*Bulletin No. 26*) reported that twilight decreases auroral sightings when the angle at which the sun is depressed below the horizon is less than 18°. The maximum solar depression angle at Ellsworth Station is about 12°, and observations are difficult to make before April and after August. The longest period of good auroral visibility for Ellsworth is at the austral winter solstice, in late June; by contrast, this is the shortest night of the year in the

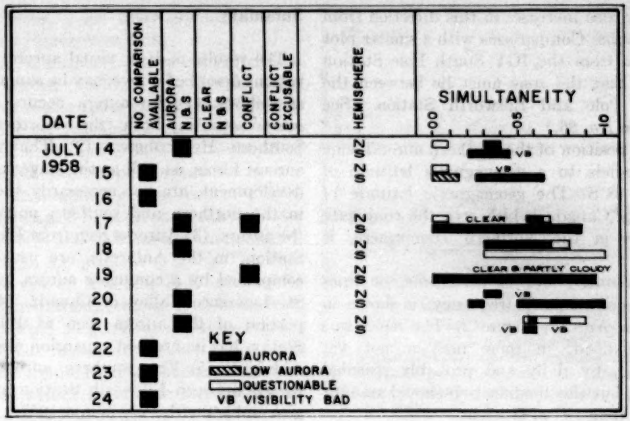

Fig. 10. *Method of Comparing Auroral Occurrences in the Two Hemispheres on a Day-to-Day Basis.*

Northern Hemisphere, where visibility of auroras is lowest in June.

Besides limitation in the number of hours of darkness, moonlight and bad weather also hampered the accumulation of visual auroral data. Poor conditions in either hemisphere made comparison impossible and, in fact, ruled out many nights entirely.

Ellsworth Station auroral data for the last six months of 1957 were checked against those for the entire United States, and it was found that, on a nightly basis, an aurora in one hemisphere was almost always accompanied by an aurora in the other hemisphere. In analyzing the 1958 data, visibility conditions were checked more throughly and Northern Hemisphere auroras occurring west of 80°W were ruled out in order to reduce any longitudinal discrepancy with observations at Ellsworth, which is at about 42°W.

A day-to-day comparison of Northern and Southern Hemisphere visual observations from March 20 to September 27, 1958, shows a total of 54 nights with corresponding auroras, two nights when both regions were definitely clear, and 20 nights with conflicting observations. (Fig. 10 is an example of the format of this day-to-day comparison.)

It is worth noting that in all of the conflicts, an aurora was reported at Ellsworth but not in the United States. Perhaps the major reason for this is that Ellsworth Station is at a higher geomagnetic latitude than the United States and more auroras are seen. Another reason, however, is that visibility was impaired on all but a very few of the occasions when an aurora was *not* seen at Ellsworth, thus preventing comparison with Northern Hemisphere observations on those occasions. Northern Hemisphere observations, on the other hand, were not so dependent on local visibility conditions as they were made over a broad network of stations.

Of the 20 conflicts, nine consisted of reports of "clear and no aurora" by observers in the United States who were located too far away from the conjugate of a small Southern Hemisphere aurora to see it. In each of the 11 remaining conflicts, at least one observer reported "clear" when the

conjugate to a southern aurora should have been visible. On five, and possibly six, of these occasions, a conjugate aurora was seen elsewhere in North America.

The investigations discussed above indicate that there is a correlation between auroral occurrences at Ellsworth Station and in North America. However, it should not be expected that every aurora will necessarily be accompanied by a conjugate aurora in the opposite hemisphere, since the comparison data showed several borderline cases and some definite exceptions.

Comparison of Forms

Comparisons indicate that the forms of simultaneous auroras in the two hemispheres frequently do not correlate with each other. On some occasions, glows occurred in the Northern Hemisphere while flames were seen in the Southern, or vice versa. Combinations such as rayed arcs in contrast to diffused surfaces, rays and surfaces to multiple arcs, and homogeneous arcs to pulsating surfaces come and go with no apparent interconnection. Hence, it appears that the forms are determined independently.

This conclusion should not be accepted without some reservation, however, as the forms do not always differ; on many days, the simultaneous auroral displays were similar in that the forms in both hemispheres were either active or inactive. Further, on one impressive occasion (April 16, 1958), previously quiet auroras in both hemispheres erupted suddenly and approximately simultaneously (within the accuracy limits of the reports) into active displays of rays, rayed arcs, and flames.

Geographic Position, Extent, and Variations

If a correspondence exists between auroras in the Northern and Southern Hemispheres, there should also exist correlations between their geographic positions and extent and in daily and seasonal variations of these factors. Attempts were made to find such correlations by plotting the data in several different ways. Graphs similar to that shown in Figure 7 were compiled to show the locations and extents of simultaneous auroras in the Northern and Southern Hemispheres, the approximate breadth of the auroral zones, and the corresponding latitudes of occurrence, in each hemisphere, of simultaneous auroras.

Graphs showing the positions of auroras at different times of the year were examined for indications of possible seasonal changes in the positions. An apparent shift is shown in 1957 from higher to lower north geomagnetic latitudes and from lower to higher south geomagnetic latitudes, but this shift is not repeated the next year. Indeed, in 1958, there appears to be a shift in the other direction. The positional shifts, then, must be related to differences in the individual auroras rather than to seasonal effects.

The simultaneous greatest extents of auroras, simultaneous arc forms, and nightly greatest extents were plotted on graphs in further efforts to identify daily or seasonal patterns. Observational data were also plotted on a yearly basis for this purpose. All of these plots showed scattering of points with no evidence of distinct patterns.

A time-of-day breakdown of 1957 data was also made, since, in such a breakdown, a shift in auroral positions can be predicted. No shift was visible, however. As the greatest extent of an aurora in each hemisphere occurs at about local midnight, auroras observed from Ellsworth Station would have their peaks near 0300 UT and Northern Hemisphere auroras observed in eastern North America near 0500 UT. From 0300 to 0500, then, the southern auroras should retreat and the northern auroras advance. No such effects are visible in the graphical data, again indicating that they are outweighed by the individual characteristics of the auroras.

Conclusions

Visual auroral observations made at IGY Ellsworth Station, Antarctica, and in North America during the IGY were compared to investigate the question of simultaneity of auroras in the Northern and Southern Hemispheres, and to determine the characteristics of such conjugate auroras—location, extent, and daily and seasonal variations.

Although a correspondence between auroral zones was determined, the peculiarities of the individual auroras obscured any seasonal and daily variations that may have occurred. This does not mean such variations do not exist, however. Over-all relations dominated the findings because the volume of data was such that finer auroral characteristics were evened out statistically. If more data or some other way of normalizing the auroral individualities are used, daily and seasonal variations may become apparent.

Status of Report Series of IGY World Data Center A

The following report is based on a detailed, annotated booklet, "List of IGY Report Series," available from IGY World Data Center A, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington 25, D. C., or from any of the subcenters of WDC-A.

IGY World Data Center A was established in the United States as one of three World Data Centers which collect complete sets of data from the observations conducted during the International Geophysical Year. WDC-A activities include the publication of seven series of reports to assist in fulfilling and supplementing the obligation of the WDC's to make IGY and IGC results available to interested scientists. Three of these series—Rocket, Satellite, and General Reports—are available from the National Academy of Sciences. Four series—Aurora (Instrumental), Glaciology, Oceanography, and Solar Activity Reports—are available directly from the relevant subcenter of WDC-A.

Each report in the Rocket, Satellite, and General Report Series is priced at $1.00, postage prepaid. Orders should be addressed to: Printing and Publishing Office, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington 25, D. C.

Standing orders may be placed for: (1) Rocket Report Series—Satellite Report Series. (This standing order automatically includes both Rocket and Satellite Reports. Standing orders cannot be placed for the Rocket or Satellite Reports separately.) (2) General Report Series. Publications on standing order are mailed as issued, postage prepaid, and are billed for periodically at a 15% discount from list price. (Orders from agencies should be accompanied by appropriate purchase forms.)

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No. 2. Preliminary Report on Expedition Downwind, University of California, Scripps Institution of Oceanography, IGY Cruise to the Southeast Pacific, edited by R. L. Fisher. 79 pp., June 1958.

No. 3. Preliminary Reports on the IGY Pendulum, Gravimeter and Seismological Programs at

the University of Wisconsin, by George P. Woollard. 31 pp., July 1958.

No. 4. Some Aspects of the Antarctic Atmospheric Circulation in 1958, by Jean Alt, Paul Astapenko, and N. J. Ropar, Jr. 110 pp., May 1959.

No. 5. United States Program for the International Geophysical Year, 1957–58. 90 pp., Sept. 1959. (Program and station lists for United States participation in the IGY.)

No. 6. United States Program for International Geophysical Cooperation—1959. 69 pp., Sept. 1959. (Program and station lists for United States participation in IGC-59 program. Appendix I—United States National Space Science Program, Report to COSPAR; Appendix II—United States Program for Antarctic Scientific Research 1959, Report to SCAR.)

*No. 7. Interim Catalogue of Data in IGY World Data Center A. 169 pp., Nov. 1959.

*No. 8. Fifth Six-Monthly Catalogue of Data in IGY World Data Center A. 206 pp., Feb. 1960.

No. 9. IGY Meteorological Data on Microcards, compiled by William M. McMurray. 142 pp., June 1960.

*No. 10. Sixth 6-Monthly Catalogue of Data in IGY World Data Center A. 154 pp., July 1960.

No. 11. The Topography of the 400°K Isentropic Surface over Antarctica: Spring 1957, by Ronald C. Taylor. 72 pp., October 1960. (Also contains a reprint of "The Vernal Breakdown of the Stratospheric Cyclone over the South Pole," by C. E. Palmer and R. C. Taylor, from the *Journal of Geophysical Research*, Oct. 1960.)

No. 12. Report on IGY Visual Auroral Observations, by Carl W. Gartlein and Gale C. Sprague. 103 pp., Nov. 1960.

No. 13. Seventh 6-Monthly Catalogue of Data in IGY World Data Center A. 229 pp., Jan. 1961. (Cumulative catalogues of data received by the eleven subcenters of WDC-A during the period 1 July 1957–31 Dec. 1960.)

*Superseded by subsequent cumulative catalogue.

Rocket Report Series

No. 1. Experimental Results of the U. S. Rocket Program for the International Geophysical Year to 1 July 1958. 236 pp., July 1958. (Thirty papers.)

No. 2. Flight Summaries for the U. S. Rocketry Program for the International Geophysical Year, Part 1: 5 July 1956—30 June 1958. 193 pp., March 1959.

No. 3. Flight Summaries for the U. S. Rocketry Program for the International Geophysical Year, Part II: 23 May–31 December 1958. 120 pp., Sept. 1959.

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No. 5. Upper Air Densities and Temperatures from Eight IGY Rocket Flights by the Falling-Sphere Method, by L. M. Jones, J. W. Peterson, E. J. Schaefer, and H. F. Schulte. 102 pp., Dec. 1959. (Includes a reprint from the *Journal of Geophysical Research*, Dec. 1959, of an article by the same authors, based on the results of these and other rocket flights.)

No. 6. A Second Compilation of U. S. IGY Rocket Program Results. 198 pp., Nov. 1960. (Twenty-two papers reprinted from several journals and symposia.)

Satellite Report Series

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No. 3. Some Preliminary Reports of Experiments in Satellites 1958 Alpha and 1958 Gamma. 100 pp., May 1958. (Five articles by various authors.)

No. 4. Observational Information on Artificial Earth Satellites, by J. A. Hynek and G. F. Schilling. 38 pp., July 1958. (Nine papers.)

No. 5. Radio Observations of Soviet Satellites 1957 Alpha 2 and 1957 Beta 1, by James W. Warwick. 50 pp., July 1958.

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No. 7. Simplified Satellite Prediction from Modified Orbital Elements, by Leonard N. Cormier, Norton Goodwin, and Reginald K. Squires. 54 pp., Jan. 1959.

No. 8. Ephemeris of Satellite 1957 Alpha 2 and Collected Reports on Satellite Observations, by various authors. 122 pp., June 1959. (Part I: Ephemeris; Part II: Ten papers.)

No. 9. Symposium on Scientific Effects of Artificially Introduced Radiations at High Altitudes. 88 pp., Sept. 1959. (A reprint from the *Proceedings of the National Academy of Sciences*, Aug. 1959, pp. 1141–1228, containing seven papers, by various authors, presented at a symposium of the National Academy of Sciences.)

No. 10. The Determination of Ionospheric Electron Content and Distribution from Satellite Observations, by O. K. Garriott. 65 pp., Jan. 1960.

No. 11. Observations of Corpuscular Radiation with Satellites and Space Probes. 125 pp., June 1960. (Contains 14 articles, by various authors, reprinted from several journals and symposia.)

No. 12. IGY Satellite Ionospheric Research. Based on observations of 1957 Alpha 2 and 1958 Delta 2. 80 pp., Dec. 1960. (Three papers by various authors.)

No. 13. Satellites 1958 Alpha and Gamma: High Intensity Radiation Research and Instrumentation. (Transcript of remarks by J. A. Van Allen on May 1, 1958, and two papers by G. H. Ludwig.) 106 pp., Jan. 1961.

Aurora (Instrumental) Report Series

Address inquiries regarding the Aurora Reports to: IGY World Data Center A: Aurora (Instrumental),

Geophysical Institute, University of Alaska, College, Alaska.

No. 1. Riometer Records of 27.6 Mc/s Cosmic Noise for Thule, Barrow, and Ft. Yukon, compiled by Harold Leinbach. 119 pp., Sept. 1960.

No. 2. Riometer Records of 27.6 Mc/s Cosmic Noise for College and Farewell, compiled by Harold Leinbach. (in preparation).

No. 3. Riometer Records of 27.6 Mc/s Cosmic Noise for King Salmon and Unalaska, compiled by Harold Leinbach. (in preparation).

Glaciological Report Series

Each report is priced at $3.35 ($3.00 plus 35 cents for postage and handling). Standing orders may be entered. Address all inquiries regarding the Glaciological Reports to: IGY World Data Center A: Glaciology, American Geographical Society, Broadway at 156th Street, New York 32, New York.

No. 1. Preliminary Reports of the Antarctic and Northern Hemisphere Glaciology Programs. 144 pp., July 1958 [2nd edition, 1959]. (Fourteen reports, by various authors, in two parts: Antarctic Program—six reports; Northern Hemisphere Program—eight reports.)

No. 2. Oversnow Traverse Programs, Byrd and Ellsworth Stations, Antarctica, 1957–58: Seismology, Gravity, and Magnetism, by Edward Thiel, Charles R. Bentley, Ned A. Ostenso, and John C. Behrendt. 139 pp., July 1959. (Seven reports.)

No. 3. Deformation of the Ross Ice Shelf near the Bay of Whales, Antarctica, by James H. Zumberge, Mario Giovinetto, Ralph Kehle, and John Reid. 148 pp., May 1960.

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Solar Activity Report Series

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No. 1. Intermediate Reports of Surges and Active Prominence Regions, July–September 1957. 97 pp., May 1958.

No. 2. Intermediate Reports . . . , October–December 1957. 93 pp., May 1958.

No. 3. Intermediate Reports . . . , January–March 1958. 91 pp., June 1958.

No. 4. Observations of the Solar Electron Corona, September 1956–January 1958, by G. Newkirk, Jr., G. W. Curtis, and K. Watson. 48 pp., Aug. 1958.

No. 5. Intermediate Reports . . . , April–June 1958. 92 pp., Jan. 1959.

No. 6. Intermediate Reports . . . , July–September 1958. 93 pp., Jan. 1959.

No. 7. Intermediate Reports . . . , October–December 1958. 93 pp., June 1959.

No. 8. Intermediate Reports . . . , January–March 1959. 93 pp., Sept. 1959.

No. 9. Intermediate Reports . . . , April–June 1959. 92 pp., Feb. 1960.

No. 10. Intermediate Reports . . . , July–September 1959. 93 pp., April 1960.

No. 11. Intermediate Reports . . . , October–December 1959. 93 pp., June 1960.

No. 12. McMath-Hulbert Observatory Working List of IGY Flares, by Helen W. Dodson and E. Ruth Hedeman. 153 pp., June 1960. (Covers the period 1 July 1957–31 Dec. 1958.)

No. 13. Indices of the Solar Corona, July 1957–December 1959, by Dorothy Trotter. 57 pp., Dec. 1960.

No. 14. Flare Index for Each Day of IGY Based on McMath-Hulbert Observatory Working List of IGY Flares, by Helen W. Dodson and E. Ruth Hedeman. 17 pp., Jan. 1961.

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IGY BULLETIN

A monthly survey of programs and findings of the International Geophysical Year and the International Geophysical Cooperation–1959 as related primarily to United States programs. The Bulletin *also reports on international programs in geophysics and space science that have grown out of the IGY, and on their results.*

Correlation of Visual and Subvisual Auroras with Changes in the Outer Van Allen Radiation Zone

The following account is based on a more complete report by B. J. O'Brien and J. A. Van Allen of the State University of Iowa, F. E. Roach of the National Bureau of Standards' Boulder Laboratories, and C. W. Gartlein of the IGY World Data Center A for visual auroral data, at Cornell University. The original report appeared in the Journal of Geophysical Research, *September 1960.*

During a severe geomagnetic storm on November 28, 1959, while active visual auroras and a subvisual monochromatic red arc were observed over the northern United States, geiger counters aboard the Explorer VII satellite (1959 Iota) detected anomalous patterns of radiation in the outer Van Allen zone over these same regions. The correlation of these observations constitutes direct evidence of the "dumping" into the upper atmosphere, during times of geomagnetic disturbance, of particles from the "horn" of the outer radiation zone. (See *Bulletin No. 30* for a more detailed discussion of the Van Allen zones of geomagnetically trapped radiation, and *Bulletin No. 36* for additional information on the "dumping" process.)

The visual auroral observations were made by networks of volunteer observers and of all-sky cameras. Both these observing systems were set up as part of the IGY Visual Aurora Program under the direction of the group of auroral physicists at Cornell University.

The subvisual monochromatic arc was detected by photoelectric photometers installed and operated by the National Bureau of Standards at Fritz Peak, Colorado, Sacramento Peak, New Mexico, and Cactus Peak, California, as part of an IGY network of airglow stations. In these arcs, discovered by D. Barbier of the Haute Provence Observatory, France, early in the IGY, radiation at 6300 A (a red line of atomic oxygen) is dominant over the 5577 A radiation (a green line of atomic oxygen) prominent in most visible auroras. (A more-detailed discussion of the 6300 A arcs appeared in *Bulletin No. 36.*)

Explorer VII, which made the correlative radiation measurements in the outer Van Allen zone, was launched under sponsorship of the National Aeronautics and Space Administration on October 13, 1959. At the time of these observations, the satellite's apogee altitude was about 1085 km (675 miles) and its perigee altitude was about 555 km (345 miles). (*Bulletin No. 29* gives additional information on the satellite and its experiments.)

Comparison of Satellite and Visual Auroral Observations

Satellite Observations: Figure 1 shows the counting rate versus time of each geiger tube carried by Explorer VII as the satellite traversed the outer zone traveling northward, and then southward through it again, on its pass over North America between 0355 and 0415 UT on November 27, 1959, when the radiation zone was relatively stable. The pattern for the corresponding pass on November 28 in very nearly the same position in space is also shown, and it is apparent that marked changes have occurred. Finally, to complete the sequence, the corresponding pass on November 29 is shown.

A notable feature of this figure is the very intense radiation peak at 0335:30 UT on November 28. Among many hundreds of samples of radiation in the outer zone measured by Explorer VII, this peak is unique in two respects: it is the narrowest peak seen to date (the satellite traversed it in three seconds), and it contains the softest radiation seen to date, with a ratio of Anton 302 to Anton 112 counting-rates of 27 to 1 compared with the usual outer-zone value of about 14 to 1. (The Anton 302 counter detects X-rays from electrons with energies greater than about 30 kev and the Anton 112 detects X-rays from electrons with energies greater than about 70 kev.)

Visual Observations: All-sky-camera photographs taken at 0336 and 0337 UT on November 28 at Choteau, Montana, by J. G. Robison, show a broad auroral arc at the zenith. A fainter aurora extended at least 0.5° to the south, and a diffuse, medium-intensity arc joins the main arc on the northern side. E. G. Schmidt, a visual observer at Browning, Montana, also observed this feature at 0345 UT. This auroral form began at about 0300 UT, and by 0335 UT it had moved southward about 3.5° of latitude. It continued southward another 1.5° and then changed into a ray structure at about 0455 UT.

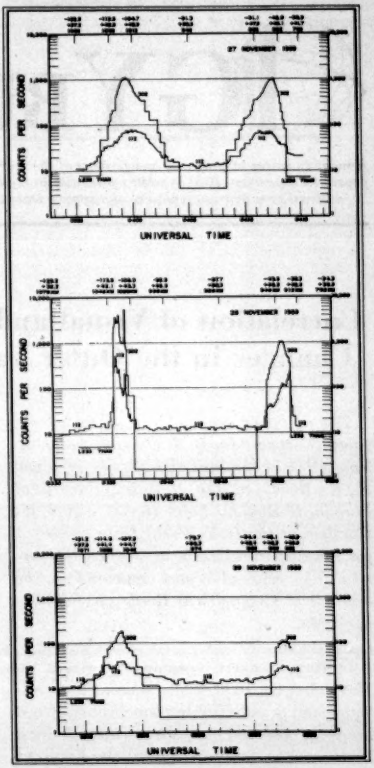

Fig. 1. *True Counting-Rates of Anton 302 and 112 Geiger Tubes on Explorer VII (1959 Iota) During Passes over North America at Roughly the Same Position in Space on November 27, 28, and 29, 1959. Graphs aligned according to time satellite crossed geographic latitude 40° N.*

Correlation: These broad auroral forms were plotted from all-sky photographs to show ground positions of overhead auroras (Fig. 2). The lower edge of the bright arc, as delineated by the visual observer, corresponds to the junction of bright and me-

dium aurora in the figure. The subsatellite locus is also plotted, and this path is projected at right angles to the isocline down the magnetic field lines to give the path projected on the ground. Hatching between the projection lines shows radiation intensities measured by the 302 tube, with three peaks exceeding 3000 counts/sec (see Fig. 1). The downward projections of the anomalous outer-zone structure lie over the auroral forms. Hence, if charged particles detected by the satellite in the structure continued spiraling down the magnetic field lines they would have coincided in space and time with the aurora.

More-detailed discussion of the relationship between the satellite-observed particles and the visible aurora is necessarily tentative, owing to inadequate knowledge of the spectrum and altitude-dependence of particle intensity. Simple considerations of particle energy show that the qualitative correlation established above is also quantitatively plausible.

On the basis of present knowledge, it is reasonable to suppose that the particles detected by the satellite equipment are electrons whose number-energy spectrum rises steeply toward low energies. For a typical particle energy of 50 kev (50,000 electron volts) it is found by laboratory measurement that the counting rate of the 302 counter must be multiplied by a factor of the order of 10^7 to 10^8 to obtain the omnidirectional intensity of electrons. Hence, the energy flux at the position of the satellite is likely to be of the order of 10^4 ergs/cm^2/sec (or greater), or some 5×10^5 times the optical energy emitted in the 5577 A spectral line of an easily visible aurora of 10 kilorayleigh brightness (International brightness coefficient II).

C. E. McIlwain in 1960 found from data obtained by rocket flights into auroras over Fort Churchill, Canada, that the gross efficiency of excitation of atmospheric emissions in the visible region by electrons of similar energy is about 0.2%. Thus, the peak energy flux measured by Explorer VII on this occasion was several hundred times that required to excite the observed aurora. Indeed, this factor may be considerably greater if electrons below the detection threshold of the satellite-borne 302 counter are present.

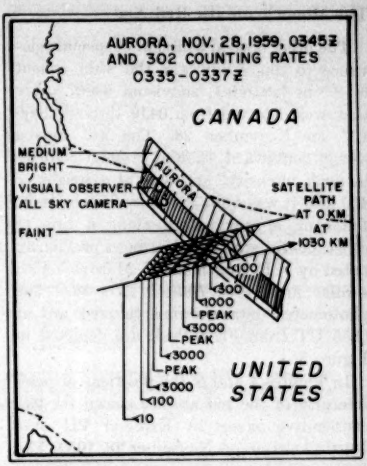

Fig. 2. *Comparison of Positions of Auroral Arc and of Satellite Radiation Measurements in "Horn" of Outer Van Allen Zone over North America at 0336 UT, November 28, 1959. Three heavy lines show projections of counting-rate peaks from satellite orbit down along magnetic-field lines to ground. (<3000 represents counting rate between 1000 and 3000/sec; <1000—300 to 1000/sec; <300—100 to 300/sec; and <100—10 to 100/sec.)*

From the above considerations it appears plausible that the particles in question are in quasi-trapped orbits in the geomagnetic field and are absorbed in the atmosphere after hundreds of latitudinal oscillations (i.e., in a period of time of the order of tens of minutes.) The temporal stability of the arc is an indication that the aurora was not excited by instantaneous dumping of an intense particle flux.

The Monochromatic Red Arc

The other optical emission of special relevance to this study was the wide (about 6°-8° in latitude), sudvisual 6300 A arc that was detected from 0410 through 1000 UT on November 28. The arc moved slowly southward, showed gradual changes in peak intensity, and was at a height of 400 km. It was quite extensive in longitude, following approximately along a line of constant dip angle, as has been previously noted by F. E. Roach and E. Marovich with similar arcs. (See *Bulletin No. 36.*) The photometer data showing the red arc at 0855 UT from Fritz Peak are depicted in Figure 3.

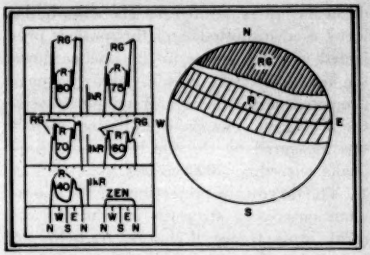

Fig. 3. *Fritz Peak Photometer Record for 0855 UT, November 28, 1959. At right is deduced geographic location of subvisual 6300 A monochromatic red arc (R) and of visual auroral activity (RG) consisting of 6300 A and 5577 A radiation.*

In Figures 4 and 5, the positions of peak intensity of the red arc are shown for two consecutive passes by Explorer VII over North America on November 28, 1959. The latitude thickness of the red arc is indicated roughly by the two lines of constant dip at 66° and 72°. The pertinent satellite path on each pass projected along magnetic lines to the red-arc altitude of 400 km is shown on these maps together with a logarithmic sketch of the Anton 302 counting rate during each pass. (A report by Roach, J. G. Moore, I. C. Bruner, Jr., H. Cronin, and S. M. Silverman, describing how the height of 400 km was estimated, appeared in the November 1960 issue of *JGR.*)

The photometric and satellite observations plotted on the maps were made nearly simultaneously. Plausible extrapolation in longitude of the red arcs on the maps shows a striking positional correlation with the satellite observations. The two classes of observations shown on a map for 0855 UT, when the satellite traveled southeastward along the arc, were coincident in both space and time, and provide even more convincing evidence of their relationship. Both the peak counting rates and the red-arc intensity decreased from pass to pass.

In view of the similarity of the locations and widths of both the red arc and the outer zone (as defined by the 302 counter), and in view of the gradual decrease in intensity of each, the investigators believe that the two are associated. In particular, it appears that the gradual depletion of the outer zone may be due to progressive atmospheric scattering-down and absorption of trapped particles, and that the corresponding energy influx may be the source of energy for the excitation of the 6300 A radiation.

From calculations similar to those used in the discussion of the visual aurora, above, it is estimated that the presumed influx of energy from the detected particles could have maintained a 6300 A arc with an intensity of one kilorayleigh for a period of the order of 10 hours only if the efficiency of excitation is several percent.

Other Relationships and Problems

Observations by R. L. Arnoldy, R. A. Hoffman, and J. R. Winckler with instrumentation in Explorer VI show that there was a very great loss of trapped radiation near the equatorial plane after a sudden geomagnetic-storm commencement in August 1959. As the August event seemed similar in nature to that of November 1959, this evidence may be cited to support the investigators' belief that the decreasing intensity at altitudes of about 1000 km is

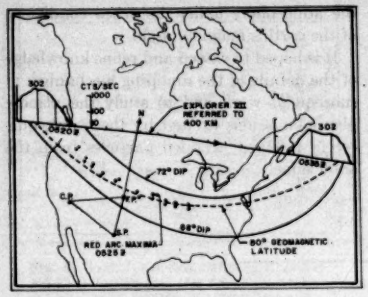

Fig. 4. *Positions of Red-Arc Maxima and Explorer VII Data, 0525 UT, November 28, 1959.*

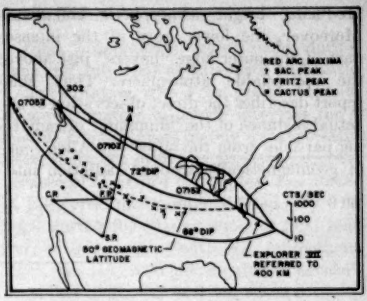

Fig. 5. *Positions of Red-Arc Maxima and Explorer VII Data, 0715 UT, November 28, 1959.*

In both of above figures, satellite data is projected downward to the red-arc height of 400 km; the Anton 302 counting rate is shown on a logarithmic scale on the satellite locus; geomagnetic latitude 50° N is shown; and the 66° and 72° dip lines roughly define the width of the red arc.

due to the absorption of these particles in the atmosphere and not to the other conceivable alternative—gradual upward drift of their mirror points to an altitude above that of the satellite observations.

Many problems remain unanswered in this study. For example, for the occasion investigated there is no knowledge of fluxes of electrons below about 30 kev, and knowledge of the efficiency of energy conversion from electron kinetic energy into optical emissions is insufficient. A further considerable and long-standing problem lies in the fact that, in the red arc, little or no 5577 A radiation was emitted even though the energy required to raise atomic oxygen to the parent level for this spectral line is only 2 ev more than to lift it to the parent level for 6300 A radiation. (G. A. M. King and Roach, in a report appearing in the March 1961 issue of the National Bureau of Standards' *Journal of Research, D—Radio Propagation*, suggest that the effect may be due to a heating of the ionosphere, resulting in an enhancement of the reactions

$$\begin{cases} N_2 + O^+ \rightarrow NO^+ + N \\ NO^+ + e \rightarrow N + O(^1D). \end{cases}$$

This second reaction can excite atomic oxygen to ^1D (2.0 ev) but not to ^1S (4.2 ev) since it is 2.75 ev exothermic.)

Correlation of the red arc with the aurora under the radiation peak at 0336 UT is also uncertain. The intensity of a few kilorayleighs of 6300 A radiation would be insufficient to register either on the human eye or on the all-sky-camera photographs. Previous observations by Roach and Marovich showed conclusively that a 6300 A arc was not merely above a green auroral feature, but indeed on the low-latitude fringe of an aurora containing 5577 A radiation (i.e., was geographically distinct from it). If it is assumed that the 6300 A arc on November 28, 1959, was of a similar type, it would be supposed that the RG area of Figure 3 was seen by the visual observer and the all-sky camera whereas the red arc, R, was not.

Conclusions

Since the early work on geomagnetically trapped radiation, it has been clear that the particles present in the outer Van Allen zone have the potential capability of

producing bright atmospheric emissions. Moreover, the lower horn of the intense part of the outer zone "hovers" just above the appreciable atmosphere. Thus, this report describes the direct observation of an actual instance of the "dumping" of radiating particles from the outer Van Allen zone of geomagnetically trapped radiation into the atmosphere under disturbed conditions of the earth's magnetic field.

It is hoped to extend and refine knowledge of the details of the dumping mechanism in subsequent work and to study the atmospheric emissions excited by the usual, quiescent influx of trapped particles from the outer zone.

Ocean Tide Measurements from Antarctic Ice Shelves Using Gravity Techniques

The following material is taken from a more-detailed report, by Edward Thiel, A. P. Crary, R. A. Haubrich, and J. C. Behrendt, published in the Journal of Geophysical Research, *February 1960. Thiel, Crary, and Behrendt were members of wintering-over parties at Little America and Ellsworth IGY Stations at the time these studies were made, and Haubrich later assisted in analyses of computer data. At present, Thiel is associated with the University of Minnesota, Crary is Chief Scientist for the US Antarctic Research Program, and Haubrich and Behrendt, respectively, are associated with the Scripps Institution of Oceanography and the University of Wisconsin.*

Although the rise and fall of ocean waters along coasts was perhaps one of the first geophysical phenomena studied by man, the measurement of tides in the open ocean remains a difficult problem, as platforms from which such measurements are attempted themselves rise and fall with the tide. Measurements from surface vessels using anchor and line are not sufficiently accurate, and the use of pressure recorders resting on the bottom in deep water involves serious difficulties. It seems likely, therefore, that some new technique may ultimately prove best for tidal measurements at sea.

Gravimetric determinations of the ocean tide were made during the austral midwinter of 1957 at Ellsworth and Little America IGY stations, established on floating ice shelves on opposite sides of Antarctica (see Fig. 6). Ellsworth Station, at 77° 42.6′ S, 41° 08′ W, on the Filchner Ice Shelf, is 2 km from the ice front and 115 km from the nearest land. The station is at an elevation of 42 meters and the ice shelf beneath it is 232 meters thick. The ocean depth below the station, determined by seismic methods, is 792 meters. Little America Station, at 78° 11.9′ S, 162° 16′ W, on the Ross Ice Shelf, is 5 km from the ice front and 2 km from an embayment in the ice shelf, Kainan Bay. It is 60 km from Roosevelt Island, the nearest land. The ocean floor at this location is 578 meters below sea level, the station elevation is 44 meters, and the ice shelf is 259 meters thick.

The vertical movements of the ice shelves observed with gravity meters are of two general types: (i) the rise and fall of the shelf in response to ocean tides, and (ii) a

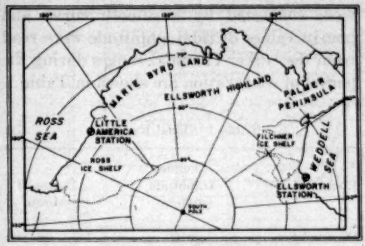

Fig. 6. *West Antarctica, Showing Ross and Filchner Ice Shelves and Locations of Little America and Ellsworth IGY Stations.*

high-frequency, oscillatory motion of nontidal origin, with periods ranging from about 15 to 50 seconds.

Oscillations at the Ice Front

Oscillations similar to those observed in the Antarctic were previously noted by Crary and others in the Arctic Ocean during gravity meter readings on pack ice 2 meters thick and on a floating ice island 60 meters thick. It is believed that these oscillations are of oceanic origin and are influenced by the amount of ice cover. At Little America Station, when there was extensive open water offshore in February 1958 (austral summer), the tidal oscillations were too large to be read on the instrument scale; by April, however, when very little open water remained in the Ross Sea, the amplitude of the oscillations had decreased greatly and the scale could again be read easily.

These high-frequency vibrations damp out fairly rapidly inland from the ice front. At a distance of 10 or 15 km from the edge, though still on the floating shelf, the gravity meter can be read as at a land station. Figure 7 illustrates the decrease in amplitude between measurements made 1.3 and 15.4 km from the ice front in October 1957, as the Ellsworth oversnow traverse team proceeded inland from the station.

Ocean Tides

Tidal observations were made during June and July 1957 at Ellsworth and Little America Station, with Frost gravity meters, at approximately bi-hourly intervals for a month. The two Frost meters were specially selected for the oversnow traverse program because of their low drift rates. The meter at Ellsworth, for example, drifted only 0.93 mgal during the 81-day summer field season, or 0.34 mgal/month. (A milligal, or mgal, equals 1/1000 gal; a gal is an acceleration due to gravity of 1 cm/sec^2.)

In addition to the small instrument drift, a change of gravity was expected to result from the slow northward (seaward) movement of the station during the time of the tidal study. The northward component of movement at Ellsworth, as determined by celestial navigation, is 1.25 km per year. According to the International Gravity Formula, this change in latitude will result in a 0.35 mgal decrease in gravity during the course of one month. However, because instrumental drift and physical drift of the station are both small, and may be expected to have opposite signs, no correction for them was made in reducing the gravity data.

The change of gravity with elevation in air at the surface of the earth is 0.3086

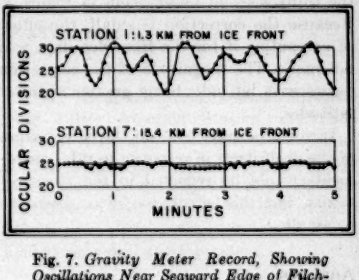

Fig. 7. *Gravity Meter Record, Showing Oscillations Near Seaward Edge of Filchner Ice Shelf and Decrease in Amplitude with Distance from Ice Edge, October 1957.*

mgal/meter. However, in the present case, the gravity meter does not simply move up and down in air; it is also necessary to apply a correction to allow for the changing thickness of the water column.

Figures 8 and 9 are plots of tidal fluctuations in the Weddell and Ross Seas, respectively, during portions of June and July 1957. The tidal variations, in meters, were computed using a formula to convert gravity variations to height. The mean gravity value for the month of observation was equated to zero so that tides could be measured as deviations, in meters, from this mean. The tidal heights, in meters, were found to be equal to 3.7653 × the gravity deviation in mgals.

In the gravimetric method, the tide is measured with respect to the center of the earth. The conventional tide, on the other hand, as measured by a tidal gage on a coast, is the change of the sea surface with respect to the adjacent rock surface, and the rock surface is subject to "earth tides" resulting from the varying attractions of the sun and moon on the solid earth. In principle, therefore, if the gravimetrically determined tide is to be compared with the conventional tide, a correction for earth tides is necessary.

The Weddell Sea data were corrected for earth tides and the magnitude of this correction is indicated by the dotted line for the third week of observation in Figure 8. Because the correction is small, the effort of computing it for the Ross Sea data was not made. The magnitude of the correction varies with latitude, being greater at lower latitudes.

It might be expected that the acceleration of the shelf itself in response to tidal movements would be reflected in the measurements, but this effect, too, was shown to be small.

Analysis

In Figures 8 and 9, the measurements are indicated by dots. These control points were connected by a smooth curve and hourly values of tidal amplitude were read from the curve. The tidal ranges during the period of observation are shown in Table 1.

Table 1—Tidal Ranges

Location	Double Amplitude (meters)	Phase of Moon
Weddell Sea	0.6	Last quarter
	3.2	New moon
	0.9	First quarter
	2.2	Full moon
	0.8	Last quarter
Ross Sea	1.4	Full moon
	0.3	Last quarter
	1.3	New moon
	0.4	First quarter
	1.2	Full moon

From the hourly data, the amplitude and phase were computed for the more-prominent tidal components. For each component, the number of hourly observations was chosen so that the time-length of the record would be close to an integral multiple of the period of that component. The tidal amplitude of several harmonics on either side of this particular harmonic were also computed to provide an estimate of the noise level inherent to the data.

Analysis of this data shows that the principal differences between Weddell Sea and Ross Sea tides are: (1) the Weddell Sea tide may be classed as a mixed tide, having both diurnal and semidiurnal components, whereas the Ross Sea tide is diurnal; and (2) the tidal amplitudes are larger in the Weddell Sea than in the Ross Sea, a fact possibly related to the shape of the basins south of the two stations.

Tidal Currents

On July 4, 1958, oceanographic studies were made at Kainan Bay, near Little America Station, including measurements with an Ekman current meter, during a 6-hour interval at depths of 300 and 400

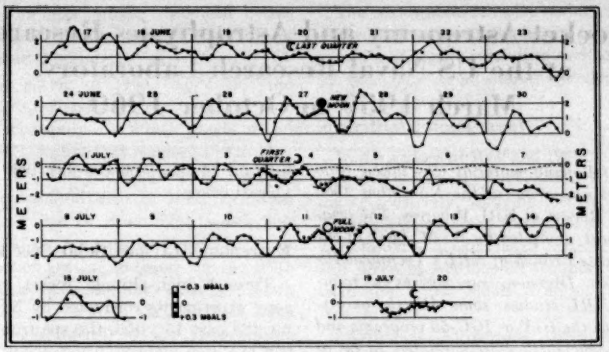

Fig. 8. *Gravity Meter Record of Weddell Sea Tides, June 17–July 19, 1957.*

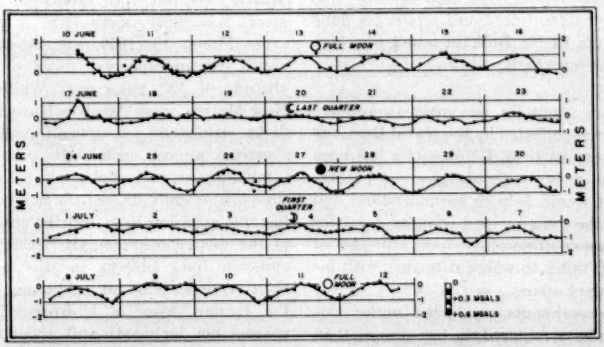

Fig. 9. *Gravity Meter Record of Ross Sea Tides, June 10–July 12, 1957.*

meters. Simultaneously, gravity measurements were made at Little America with the hope of obtaining a correlation between tidal currents and vertical shelf movements, from which the north-south dimension of the shelf might be calculated. Computations based on these measurements gave a north-south dimension of the ice shelf of 1000 km. By comparison, the actual distance from Little America Station, near the northern margin of the shelf, to the southern extremity of the Ross Ice Shelf is 840 km. It may be concluded, therefore, that the gravimetric determination of tidal amplitude is of the proper magnitude to account for the observed tidal current.

Rocket Astronomy and Astrophysics Research at the US Naval Research Laboratory, March 1959 to October 1960

The following material was taken from a report appearing in the November 1960 issue of Report of NRL Progress. *The original report, compiled by W. M. Leak of the Periodicals Branch of NRL's Technical Information Division, summarizes a number of NRL studies, some directly associated with the IGY or IGC-59 programs and others sufficiently closely related to be of interest to* Bulletin *readers. Subsections dealing with studies already reported in previous* Bulletins *have been condensed in the present treatment and references have been made to the* Bulletin *issues in which the fuller reports appeared.*

A basic program on upper-atmosphere physics was initiated by the Naval Research Laboratory in 1946. Its objective has been to obtain data on certain physical properties that would help us to understand and explain the dynamic and complex behavior of the upper atmosphere from altitudes of about 50 miles to where it merges with interplanetary space.

The experiments conducted under this program have required the use of more than two hundred rockets, including rocket-launched satellites, to carry appropriate scientific instruments for making astrophysical and astronomical measurements directly in the regions of interest or to collect data on some of the brief and elusive physical and chemical processes known or suspected to be taking place. Almost without exception, each experiment has contributed significant results that not only advanced knowledge of the physics of the atmosphere but also helped to launch the current era of space exploration. Major results of the experiments conducted in the interval March 1959–October 1960 are reviewed below.

Extreme-Ultraviolet Solar Spectra

Through high-altitude rocket spectroscopy experiments conducted by NRL during the past 15 years, the spectrum of the sun has been mapped progressively to ever shorter wave-lengths and with constantly improved resolution. Those conducted in March 1959 and April 1960 were the most recent successful experiments.

On March 13, 1959, an extreme-ultraviolet spectrograph was flown to a peak altitude of 123 miles over White Sands, New Mexico, in an Aerobee-Hi rocket. The flight yielded an extreme-ultraviolet solar spectrum almost completely free of contamination by stray light, which for a long time has severely limited the number of detectable emission lines and the observation of the solar continuum. Of the nearly 100 emission lines present in this spectrum, there were at least six additional lines of the Lyman series of hydrogen (Lyman-gamma not included) and about 60 lines that had not been observed previously in the solar spectrum.

Although the spectrograph covered the wavelength range of 500 A to 2100 A (it was more efficient in this range than spectrographs employed in previous successful flights because of improved surface coatings of higher reflectance), the shortest wavelength observed was the HeI line at 584.3 A. Among the new lines identified were those produced by NeVIII, MgX, OII, OIII, OIV, OV, NII, NIII, SI, SVI, and others. The discovery of the NeVIII lines near 800 A is the first direct proof of the

existence of neon in the sun. Still better spectographic results were obtained in a subsequent experiment.

In the spring of 1960 (April 19), the first doubly-dispersing spectrograph was flown successfully at White Sands in an Aerobee-Hi rocket that reached a peak altitude of 130 miles. This experiment resulted in an extreme-ultraviolet solar spectrum completely free of stray light, which was eliminated by a predisperser consisting of a diffraction grating to throw the spectrum of the sun onto the slit, with dispersion along the slit. Hence, for the first time, everything recorded by the spectrograph was real solar emission.

Nearly 200 intense emission lines were observed in the new spectrum, and most of these have been identified. They are lines produced by the abundant elements in the sun through sulphur, in stages of ionization as high as the eleventh. The reasonance lines of SiXII (eleventh stage of ionization) at 499.3 A and 521.1 A were the shortest photographed; they require the greatest energy for excitation in the extreme-ultraviolet spectrum of the sun and originate in the corona. In addition, 11 lines of the Lyman series of hydrogen were present (including Lyman-gamma, which is very weak because of intense absorption of this wavelength by atmospheric molecular nitrogen), and the Lyman continuum could be followed to approximately 800 A.

For the first time, the spectrum shows the continuum of the sun from 1500 A to 1000 A, where it is distinguished by the absence of the Fraunhofer lines (dark lines of solar absorption spectrum) that characterize the spectrum at longer wavelengths. Conspicuous within the continuum were absorption bands attributable to the discharge of water vapor from the rocket during flight. Quantitative data on the amount of water vapor surrounding the rocket and on the amount of atmospheric modular nitrogen above the trajectory peak will be obtained from a study of the spectra.

The extreme-ultraviolet solar spectroscopy program is continuing in an effort to obtain still higher resolution and to extend the spectrum to still shorter wavelengths.

Solar-Disk Photography

In the springs of 1959 and 1960, the Naval Research Laboratory succeeded in obtaining, respectively, extreme-ultraviolet and X-ray photographs of the sun. The pictures were taken with cameras developed at NRL and flown in Aerobee-Hi rockets launched from the White Sands Missile Range in New Mexico.

Ultraviolet Photographs: Ultraviolet photographs were obtained by a specially designed camera carried on the March 13, 1959, flight mentioned above. The images showed that Lyman-alpha is emitted with increased intensity over plage regions of the sun, as are the solar radiations produced by calcium-K and calcium-H; the enhanced Lyman-alpha emission areas match the calcium plage pattern in detail but are greater in contrast. This increase in contrast and in coarseness of detail with decreasing wavelengths is consistent with the three-dimensional nature of the solar atmosphere. The stormy appearance of the solar atmosphere at the Lyman-alpha radiation level is in agreement with the picture of ascending columns of turbulent gas, spreading, combining, and merging as they stream out of the sun. Eventually traces of these gases reach the earth. Occasionally, during periods of great solar activity, these gases produce auroras and magnetic storms and disrupt radio communications. (A more-detailed account of this experiment appears in *Bulletin No. 23.*)

An image of the sun in the light of the Lyman-beta radiation of hydrogen is among the objectives of similar experiments planned for the near future.

X-Ray Photographs: A pinhole camera ($6 \times 4 \times \frac{3}{8}$ inch) was used to obtain the first photograph of the quiet sun in its X-ray emission, as X-rays cannot be focused

by lenses or mirrors in the manner of visible or ultraviolet light. The 0.005-inch pinhole was covered with a thin plastic filter, opaque to visible light but partially transparent to soft X-rays. Wavelengths effectively transmitted were in the range 20 A to 60 A. The camera was mounted on a biaxial pointing control that aimed it at the sun throughout the rocket flight. The image on the film at the back end of the camera was only 0.1 inch in diameter, and, though the image was badly smeared in azimuth because of the rotation of the pointing control, the most interesting features of the photograph (Fig. 10) were preserved.

Fig. 10. *X-ray Photograph of the Solar Disk.*

The photograph shows the sun to be rimmed by a bright X-ray halo, and several intense spots of bright X-ray emission appear on the disk. As in the Lyman-alpha photographs, at each region of brilliant X-ray emission is a bright visible plage of calcium light. Two bright plage areas on the west limb and a bright plage in the northeast quadrant account for virtually all of the X-ray emission. Densitometry of the X-ray image indicates that the intensity corresponding to the brightest plage region is about 70 times that from the weakest region of the background. The origin of most of the X-ray emission is in active solar regions, believed to be coronal condensations overlying the plage formations, rather than in a uniform undisturbed corona. The brightest X-ray source in the photograph would require a coronal condensation eight to nine times the density of the undisturbed corona.

Lyman-Alpha Profile

High-resolution spectra of the Lyman-alpha line of hydrogen radiation from the sun were obtained successfully on July 21, 1959, and again on April 19, 1960. The spectra show a broad emission profile (Figure 11) with wings extending a distance of 1 A to either side. Across the top of the profile is a broad, shallow, central reversal similar to those present in the H and K lines of calcium and in the emission lines of the magnesium double (MgII) near 2800 A. In the center of each spectral image is a narrow, deep absorption core; the corrected half-width of the core ranges from 0.025 A to 0.04 A, which corresponds to a Doppler width for hydrogen at a temperature of 800°K to 2100°K.

The shape of the Lyman-alpha emission profile indicates that hydrogen atoms continue to exist in the sun far out in its chromosphere, where the electron density is between 2×10^9 and $3 \times 10^{10}/cm^3$ and the temperature is of the order of 100,000°K. Farther out, as the temperature rises still more, there are no un-ionized atoms left—only protons and electrons, which then "boil off" into space. This forms the "solar wind" that reaches the earth a day or two later and becomes trapped in the Van Allen belts of geomagnetically trapped radiation, discovered with satellites during 1958. From the dimensions of the absorption core produced by neutral atomic hydrogen, it is estimated that a column of 1-cm^2 cross section lying between the sun and the 60-mile level of the terrestrial atmosphere must contain about 3×10^{12} neutral hydrogen atoms.

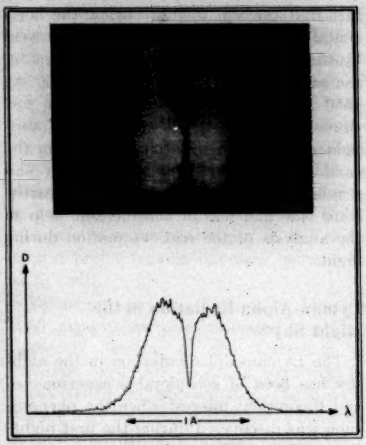

Fig. 11. *High-Resolution Spectral Image of the Lyman-Alpha Line and Its Microphotometer Tracing. The absorption core is the dark area in the very center of the spectral image.*

Night Airglow

It has been known for many years that a major portion of the light from the night sky originates in the earth's upper atmosphere. Information gained from ground-based observations has contributed greatly to studies of upper-atmospheric composition and the radiation processes that result in the airglow emissions, but the results of attempts to determine altitude distributions from ground-based observations have been unreliable. Since altitude information is of vital importance to a comprehensive study of the airglow mechanisms, a program was instituted by NRL in 1955 to measure directly the altitudes of the night airglow emissions by means of rocket-borne photometric equipment. A night airglow rocket flown on November 6, 1959, to an altitude of 140 kilometers, carried a number of photometers which yielded data on several spectral ranges of the airglow emissions.

The altitude of the maximum luminosity of the 5577 A green line of OI was determined to be 97 kilometers, in agreement with the results of earlier experiments. The maximum luminosity of radiation near 2650 A, presumably from the Herzberg bands of molecular oxygen, occurred at an altitude of about 98 kilometers, also in agreement with previous results.

Measurements of the (0–0) atmospheric band of molecular oxygen indicated an emission layer extending from 80 to 100 kilometers, with maximum emission at about 93 kilometers. The intensity of this radiation, which is self-absorbed in the atmosphere and does not reach the ground, was about 3700 rayleighs (self-absorption considerations neglected).

Two photometers were employed specifically in an attempt to measure the infrared emission of OH. The first had a filter of 180 A half-width centered at 7280 A to admit the (8–3) band. The second covered the wavelength range of 7500 A to 1 micron, approximately, and included many strong bands of OH. Data from both photometers indicated that at least three-fourths of the emitting layer was located between 75 and 95 kilometers. Continuum radiation near 5400 A was found to be concentrated at an altitude between 100 and 105 kilometers.

Ultraviolet Nebular Glow and Stellar Photometry

The ultraviolet nebular glow was discovered by NRL scientists in 1957. The discovery was made with a battery of ultraviolet-sensitive Geiger counters, flown in an Aerobee rocket, looking out through narrow collimators (about the size of hypodermic needles). These counters covered the wavelength interval from about 1225 A to 1350 A. Data collected with these instruments indicated that extensive glow regions surrounded all of the early type blue stars, the simplest case being alpha-Virginis. The nebulosity surrounding alpha-Virginis appeared almost circularly distributed out to

10° from the star, with an average surface brightness of 5×10^{-4} erg/cm²/sec.

Two recent attempts to refine these early measurements have thus far not succeeded in establishing the spectrum of the nebulosity or its geometrical distribution, even with crude resolution. The first occurred on the night of November 6, 1959. In that experiment, an ion chamber with a spectral range of 1230 A–1350 A was mounted at the focus of a single, four-inch, ultraviolet telescope (the first ever used in a rocket astronomy experiment) and flown to a peak altitude of 88 miles above White Sands. The results indicated no bright luminosities more than 4° in width and showed a number of point sources lower in far-ultraviolet intensity than anticipated. It was suspected that differences in detector short wave cutoffs may have been responsible for the disagreement with results from the 1957 experiment.

The next experiment, conducted on May 26, 1960, consisted of a flight of eight 6-inch ultraviolet telescopes, with detectors covering the interval 1050 A–1550 A, three of which accurately controlled short wave cutoffs between 1217 A and 1225 A. Unfortunately, because of sparking, only two telescopes (1280 A–1350 A and 1350 A–1550 A) yielded data. In the 1350 A–1550 A region, more than fifteen B-type stars were observed. Each of these, within the limits of the angular resolution of the instrumentation, appeared as a point source with no associated nebulosity. These same stars were observed simultaneously in the spectral band 1280 A–1350 A.

Again the observations disagree substantially with the results of the 1957 experiment. Until additional data are obtained from future flights, conclusions concerning the last two experiments are considered somewhat tentative. It can only be stated that the nebulosity does not extend beyond 1285 A.

An interesting phenomenon observed in the flight record of the May 1960 experiment merits a brief comment. Despite the fact that the sun was 22° below the horizontal, a strong glow was seen in the west by the 1280 A-1350 A detector but not by the one covering the interval of 1350 A-1550 A. It is believed that this glow was caused by the resonant scattering of sunlight near 1300 A by atomic oxygen in the earth's atmosphere. This western glow had a relatively sharp boundary on its earthward side and was of considerable help in the analysis of the rocket's motion during flight.

Lyman-Alpha Radiation in the Night Sky

The Lyman-alpha radiation in the night sky has been of considerable experimental and theoretical interest since the phenomenon was discovered during the first nighttime NRL rocket-astronomy experiment conducted in 1955.

Despite this early discovery, the origin of the Lyman-alpha glow has not been clearly demonstrated. It seems clear that a major portion of the glow is due to resonant scattering by atomic hydrogen within a geocorona, but still unknown is whether the atomic hydrogen responsible for the glow comes entirely from the earth or whether a substantial portion is interplanetary in origin.

An experiment conducted on January 14, 1960, yielded additional information which, though incomplete and not wholly understood, sheds further light on the problem. A Lyman-alpha detector, utilizing an ionization chamber filled with nitric-oxide gas and fitted with a lithium-fluoride window, was flown in a Javelin rocket launched from Wallops Island, Virginia. The effective spectral range of the detector was approximately 1050 A to 1350 A, and telemetered records from the detector were obtained over an altitude range of 350 to 1120 kilometers. The results showed that the overhead brightness decreases with altitude, the intensity at 1000 kilometers being perhaps 80% that at 300 kilometers; this behavior implies an

appreciable contribution from scattering of solar Lyman-alpha by geocoronal hydrogen. Whether this terrestrially-scattered component is or is not a major fraction of the Lyman-alpha observed at night, however, can be ascertained only by conducting experiments at altitudes still higher than 1120 kilometers. One such experiment is planned for a future deep space probe, to be equipped with a 10-inch Lyman-alpha telescope to scan the vicinity of the earth as the probe travels outward beyond 10 earth radii.

Telemetry records from the January 1960 experiment also indicated a strong "auroral" feature of the Lyman-alpha emission, with an apparent intensity of about 0.0012 erg/cm^2/sec/ster. The auroral feature may be attributed either to emission of molecular nitrogen or molecular oxygen. This conclusion is supported by unpublished data from an NRL rocket experiment conducted in the northern auroral zone (Fort Churchill, Canada) about four years ago (November 1956). On that occasion, roughly equivalent energy was recorded in the two spectral regions of 1220 A-1350 A and 1100 A-1350 A.

Solar Flares

One of the forms of solar activity that produces familiar terrestrial effects (geomagnetic storms, radio blackouts, etc.) is the flare, a sudden, short-lived brightening of the solar surface in the neighborhood of sunspots. A medium-sized flare may release an energy equivalent to millions of H-bombs, yet the mechanism of this process is not well understood. Observations of the X-ray and ultraviolet spectra of flares were started at NRL in 1956 in an effort to learn the nature of the flare phenomenon.

Rocket Studies: Accumulated evidence from instrumented rockets flown during solar flares in 1956 and 1957 showed that the total solar Lyman-alpha emission was not greatly affected by individual flares; in contrast, a considerable increase in solar X-ray emission was observed.

During July, August, and September 1959, twelve Nike-Asp rockets instrumented with photon counters, ion chambers, proportional counters, and scintillation counters to cover the range 44 A-50 A, 8 A-20 A, 2 A-8 A, and 6 A-0.1 A were launched from Point Arguello on the Pacific Missile Range. Seven produced data of geophysical interest; four of these were launched during quiet sun conditions, and three were launched during class 2+ solar flares.

Telemetry records of the data indicate substantially greater X-ray fluxes throughout the spectrum during solar flares than the values indicated for quiet-sun conditions. For example, the average background flux of soft X-rays was 0.74 erg/sec^2/cm, whereas the upper limit of values during solar flares was 9.8 erg/sec^2/cm, which is more than 10 times greater than the average background flux. The ratio of the intensity of X-rays in the 8 A-20 A region to the intensity of those in the 2 A-8 A region changed from one firing to another; a ratio of 23 was obtained for two flights during quiet-sun conditions, 7 for one flight during a bright surge prominence, and 6 for a flight 11 minutes past the peak brilliance of a class 2+ flare. The ratios indicate not only an increase in the intensity of the radiation in these wavelengths during a flare or active prominence but also a hardening of the X-ray spectrum. It appears, therefore, that the hardness of the spectrum plays a more important role than the total flux in accounting for the associated sudden ionospheric disturbances.

Another result was the discovery of extremely energetic X-rays during the most active phases of three class 2+ solar flares. Measurements in connection with the three flares revealed the presence of X-rays with quantum energies as high as 125,000 electron volts. If this radiation were thermal in origin the required temperatures in the solar atmosphere or corona would be as

high as 100,000,000°C. Previously, the most energetic solar flare radiations actually detected were of the order of 6000 to 7000 electron volts, which correspond to temperatures in the solar atmosphere of about 10,000,000°C. (Additional information on this experiment, named "Sunflare," is contained in *Bulletin No. 32.*)

Satellite Studies: Now in orbit around the earth is an NRL satellite (1960 Eta-2) containing ionization chambers (X-ray and Lyman-alpha) similar to those flown in rockets for studying emissions accompanying solar flares. It was carried aloft in piggyback fashion (atop the Navy's Transit II-A navigational satellite) by a Thor-Able-Star rocket launched from the Atlantic Missile Range, Cape Canaveral, Florida, on June 22, 1960. The ionization chambers are making continuous measurements of solar emissions in the two instrumented wavelength bands. Numerous telemetry records have been collected since 1960 Eta-2 was launched, and the progress of data analysis has now begun to reveal some of the results.

For example, on August 6, 1960, the NRL solar radiation satellite caught the early stages of a class 1+ solar flare, which lasted for 18 minutes and was accompanied by sudden ionospheric disturbances. One minute after the start of the flare, short-wave radio signals began to fade. Two minutes later, cosmic radio noise, which normally penetrates the ionosphere, also began to fade. At this point, the telemetry record showed clearly an increase in solar X-rays. Another minute later, a burst of solar radio noise was recorded (at a ground station) that persisted for two minutes, during which time the X-ray flux rose to a very high level and remained very intense after the radio noise subsided. When the satellite passed out of tracking range, the X-ray flux was still strong, but records of the next orbit around the earth, two hours later, showed that the sun was completely calm again, with no evidence of enhanced X-ray emission. Throughout this sequence of events there was no measurable increase in the flux of Lyman-alpha emission.

Thus, the Laboratory's 1960 Eta-2 satellite is providing, for the first time, a reliable time history of solar radiations and the kind and quantity of data long desired and needed for correlating these solar emissions with their terrestrial atmospheric effects. (See *Bulletin No. 42* for further discussion of this experiment and for details of the satellite's orbit and instrumentation.)